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PENGEMBANGAN KOMPONEN MODULAR MENUJU PENERAPAN *PRODUCT-SERVICE SYSTEM* (PSS) DI PT. X

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FINAL PROJECT – TI 141501

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ABSTRACT

In this global market development, greater diversification is expected and thus coerces company to have competitive advantages. Quick production lead time and high variations of product become considerations of customers, but cost of competitive advantages is the trade-off for company. This problem also faced by PT. X as commercial vehicle construction manufacturer. PT. X is using Make-to-Order system to achieve high customization of product but requires long lead time, and leads into difficulty of company to fulfill demand in peak season. In other side, PT. X also planned to implement Product-Service System (PSS) as milestone to achieve green industry standardization.

The suitable method to solve PT. X production problem is by developing modularities for parts and components, since modularity is able to reduce production lead time but increase flexibility. Components of commercial vehicle construction will be analyzed through Bill of Material and Process Chart analysis, and modules are constructed by using Modular Function Deployment. There is inventory analysis by using Periodical Review to calculate required safety stock and also cost and layout analysis as considerations to implement modularity.

The result of this research is two standardized parts and four modules which can save up to 47.19% of lead time, and increase the production capacity become 2.4, but the holding cost is Rp 6,189,021.94.

Key words: Modularity, Modular Function Deployment, Product-Service System, Standardization, Module Indication Matrix

APPROVAL SHEET

MODULAR PART DEVELOPMENT TOWARDS PRODUCT-SERVICE SYSTEM (PSS) IMPLEMENTATION AT PT. X

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CHAPTER 1
INTRODUCTION

This Final Project discussed about modularity implementation as milestone to change manufacturing system according to Product-Service System in the company. The first chapter describes background, problem formulation, objectives, limitations and assumptions, and also report writing methodology.

1.1. Background

In this global market development, greater diversification is expected and thus coerces company to have competitive advantages. Competitive advantage is obtained when company develops a set of attributes that allow company to outperform the competitors (Wang, 2014). Previously competitive advantages only focus on cost or quality, but along with global development, customers started to consider delivery, flexibility, innovation, and sustainability of products (Carayannis, 2012; Awwad et al., 2013; Shahbazpour & Seidel, 2006). From customer's point of view, there is a fierce rivalry between price of product and the degree of customization (Kumar, 2004). Customers are filled with the notion that a product is assessed based on the features, functions, and capabilities to conform customers' wants, in order to determine the price that customers are willing to pay.

From industry's viewpoint, there is a trade-off between the competitive advantage priorities and cost of investment of chosen priority. Afterward, companies are confronted with environmental issue and new requirements to be more sustainable (Dehghanian & Mansour, 2009).Therefore, business model do not only have to be economically feasible but also have to consider environmental and customers' customization issue.

This challenge is also faced by PT. X. This company runs the business of commercial vehicle construction. The products include aluminium half box, wing box, vertical box, dump truck, aluminium composite box, etc.

Figure 1.1 Sample of PT. X's Products

Figure 1.2 below shows the comparison of demand from 2013 until 2015, with the production capacity. The demand in 2014 is decreasing from 2013, and demand of 2015 is also decreasing from 2014. It may be caused by the long lead time of company which make the customers do not want to wait, and leads into order decrement. If this condition is allowed to continue, it is not impossible if the demand will continue to decline. From the graph it also can be seen that there are certain period in a year when demand is very high and more than production capacity. The area above orange line shows the number of demand that will be done with longer lead time or by doing overtime. In 2013 there are 20.56% demand excessed the production capacity, in 2014 there is 14.88% and in 2015 there is 21.07%. Those numbers show the possible loss of company since the demand cannot be fulfiled.

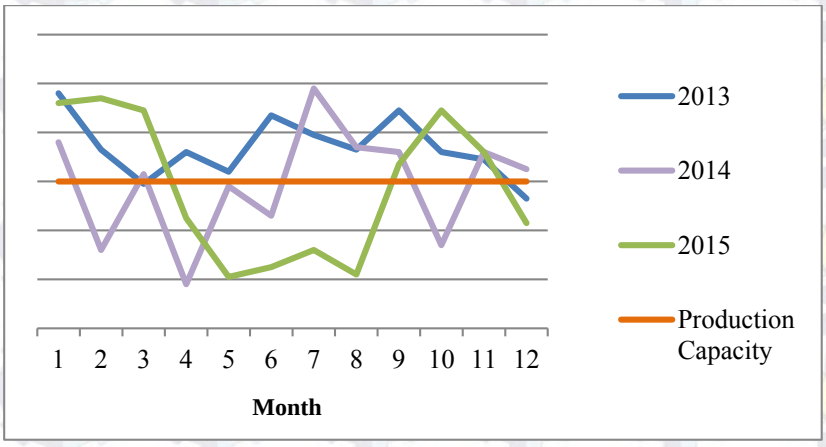

Figure 1.2 Demand Fulfil Capability of PT. X

This problem is caused by the low value of production rate, in which the production rate is related to cycle time of processes, number and complexity of components, and variations of products. Lead time become the main problem of PT. X that should be solved in oder to compete with competitors.

Actually, PT. X is a famous company especially in East Java, but this company also have to consider their competitors. Based on General Secretary of *Asosiasi Industri Karoseri Indonesia* (Askrindo), commercial vehicle construction industry will grow by at least 15% each year, and currently there are 501 commercial vehicle construction industries listed as the member of association (Bisnis Indonesia, 2015). The detail distribution of industry is provided in Figure 1.3 below. It can be seen that there are 104 companies located in East Java, which means there are a lot of competitors for PT. X. Therefore, the company should improve the competitive advantages in order to outperform the competitors.

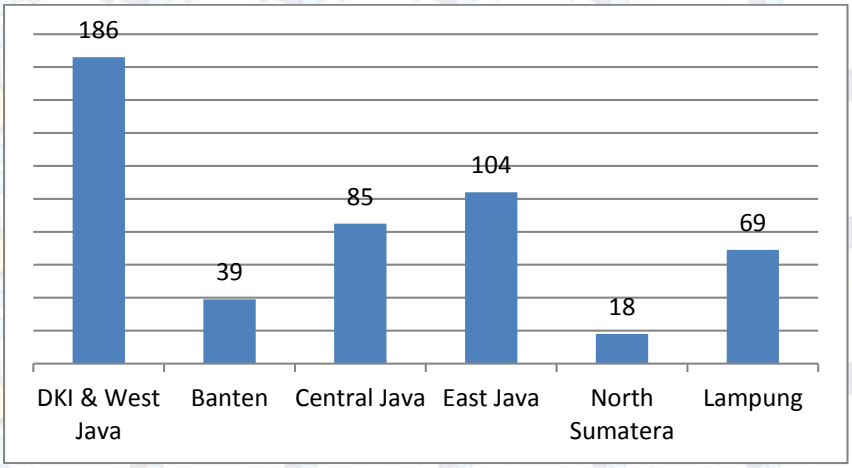

Figure 1.3. Commercial Vehicle Construction Industry in Indonesia (Bisnis Indonesia, 2015)

In an effort to upgrade the strategic competitive advantages, PT. X has tried to provide best products and services for the customers. High quality product, which is already qualified by ISO 9001:2008, is served in negotiable price with the customers. The products also delivered within the time limit in accordance with the agreement with customers. In terms of production, this company applied Make-To-Order (MTO) production system. In term of

innovation and flexibility, customers are able to order a specified design and a modified product to suit their wants and needs. PT. X has currently received green industry certification by Dinas Perdagangan dan Perindustrian Kota Surabaya. Even though it has achieved some achievements, PT. X is still eager to expand the company by implementing new system called Product-Service System (PSS).

Product-Service System (PSS) is a marketable bundle of products and services that are capable to fulfil customers' needs in an economical and sustainable manner (Reim et al., 2014; Goedkoop et al., 1999; Tukker, 2004).The main idea of PSS is about selling a set of product and services in order to attract customers but also caring the environment issues. This changing of system will affect the whole processes in the company including the production system, because previously the company only sell products but hereafter the company also attach services in the marketing, such as renting and leasing. PSS is highly related to product-life cycle. The business approach of PSS allows the company to control the flows of physical products, both the forward flow to the user and the reverse flow of products back to the provider. This new logic of material/product flows allows for adaptations along the product life-cycle. For example, maintenance and end-of-life strategies such as remanufacturing can become more beneficial due to the new circumstances that PSS provide the manufacturer. Therefore PSS is new system towards green industry issue.

Considering the future implementation of PSS in PT. X, current production system which is Make-to-Order production system will not suitable because MTO has long lead time when the number of order increasing. The production lead time become problem since there is no standardization, and even worse with the large number of components used.

Table 1.1 Number of products in PT. X

Type	Variety of products	Number of components per unit
4-wheels	16	145
6-wheels	12	175
10-wheels	8	195
Total	**36**	

Currently PT. X produces 36 products in standard (Table 1.1), but each product can be modified based on customers' wants in terms of size, materials, or other details, thus there will be at least 72 products. In which, 4-wheels car requires about 145 components and 6-wheels car requires up to 175 components. It is going to be very complicated due to large amount of components needed. Simplification is required in order to categorize the components, thus the orders can be fulfilled in short duration but still align with modification. Therefore it is important to develop standardization and modularity during the production process to meet the requirements.

McCutcheon et al. (1994) suggest that modular product design is the best way to provide product variety and production speed, which facilitate customization through the fulfilling of customer demand for variety and reduced delivery times simultaneously (Shamsuzzoha, 2010). Modular design also can reduce the number of interfaces and variety of components, while offering a greater range of final products. Modular products may be defined as assemblies or components that accomplish overall function through distinct building blocks (Stone, 2000). In a modular product development, component or module interfaces should been specified and standardized (Liang & Huang, 2002). Therefore, modularity approach is very suitable in order to help PT. X to start the PSS implementation.

In this research the observed object will be 4-wheels products since it has highest demand percentage compare to 6 and 10-wheels products (Figure 1.4), and also Table 1.2 shows that in 2014 and 2015 4-wheels product has the highest value compare to 6-wheels. The value is equal to demand multiplied by product price. While for 10-wheels the data is not available since the 10-wheels products are mostly custom thus the price is different for the product.

Table 1.2 Product Value Comparison

Product	2013	2014	2015
4-wheels	Rp 6,840,000,000.00	Rp 5,491,000,000.00	Rp 5,320,000,000.00
6-wheels	Rp 8,736,000,000.00	Rp 4,752,000,000.00	Rp 3,456,000,000.00
10-wheels	n/a	n/a	n/a

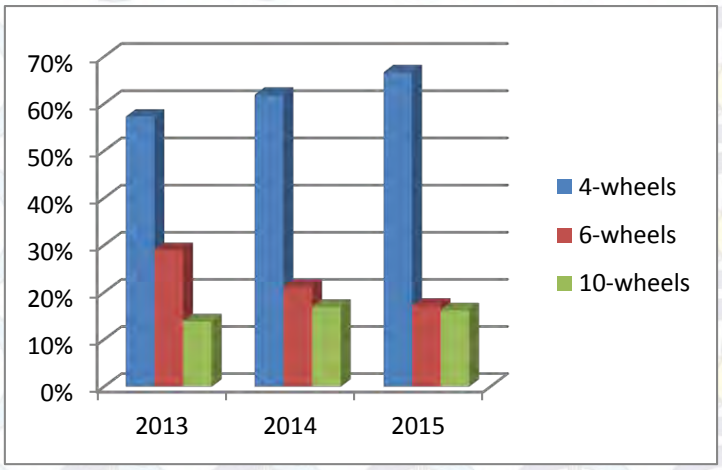

Figure 1.4. The Portion of 4, 6, and 10-wheels Demand Comparison

1.2. Problem Formulation

In order to shorten lead time, increase flexibility, and implement PSS, PT. X planned to change the production system using the concept of modularity. The shift of the production system needs to be carefully planned and investigated to ensure its success. The first problem in this research is how to change the production system using modularity concept. The second problem is to evaluate the effect of modularity implementation.

1.3. Objectives

The objective that is aimed to achieve in this Final Project is to compose standardization and modularity of product components and parts as a milestone to implement Product-Service System.

1.4. Benefits

The benefits that could be achieved through the research for the author and the company are:

1. For The Author
   a. To understand Industrial Engineer's roles in solving problem of industry.

b. To implement the theoretical knowledge to solve the real problems in industry.
c. To open the author's mindset about real industry in Indonesia, especially in Surabaya.
d. To gain deeper knowledge of modular development and Product-Service System (PSS).
e. To know modularity implementation and impact on real case

2. For The Company
a. To improve the production system performance of company.
b. To develop standard parts and modules for related products
c. To prepare company for implementing Product-Service System (PSS) in the future.
d. As a milestone for the company to achieve green industry standardization.
e. To gain better brand image through green industry certification.
f. To become a pilot project to other company in term of green industry.

1.5. Scope of Study

The scope of this study consists of limitations and assumptions used in this Final Project.

1.5.1. Limitations

The limitations used in this research are:

1. The observation is only done on 4-wheels products
2. Cost analysis only consider holding cost and labour cost
3. Layout analysis is only about space requirement analysis

1.5.2. Assumptions

The assumption used in this research is the proposed module has same mechanical characteristics with current condition

1.6. Report Structure

The structure of the Final Report can be explained as follows:

- CHAPTER I: INTRODUCTION

  This chapter explains about the basic of this Final Project including the background of study, objectives, benefits, scope of study, and the report writing methodology

- CHAPTER II: LITERATURE REVIEW

  This chapter consists of the fundamental theory as result of literature review from several references that used to support the Final Project. The literature used mainly related to Product-Service System concept, mass customization, standardization and modularity.

- CHAPTER III: METHODOLOGY

  This chapter informs about the sequences of activities that done in this Final Project and the methodology of study in order to find solution of the problems.

- CHAPTER IV: EVALUATION OF EXISTING CONDITION

  This chapter will consist of company overview, the data collection of the existing condition such as BOM Table and FPC in the company and continued by the analysis of the condition. The data and analysis is used as the evaluation of existing condition and later will be used to compare with improvement suggestion.

- CHAPTER V: PART MODULARITY DEVELOPMENT

  This chapter describes the formulation of part standardization as the pattern for the part and components. This chapter starts with technical response analysis, then the Module Indication Matrix, clustering, and then module specification.

- CHAPTER VI: DEVELOPED MODULES TESTING AND ANALYSIS

  After the standardization and modularity are done, there will be test for those improvements which will be explained in this chapter. The

trial consists of theoretical trial and case study. The case study will observe one specified product.

- CHAPTER VII: CONCLUSIONS AND SUGGESTIONS
  This chapter states the conclusions of the Final Project and suggestions that could be given for the topic.

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CHAPTER 2
LITERATURE REVIEW

This chapter explores basic knowledge about the theories in the research which are gathered from certain references such as journals, books, news, published papers, etc. The concepts discussed are Product-Service System (PSS), Make-to-Order and Make-to-Stock system, FPC, Modularity, MFD, and Periodic Review.

2.1. Product-Service System

Current era provides new ways of dealing with customers, business and value chain through service oriented approach. There are several terms introduced as this concept: servitization (Vandermerwe & Rada, 1988), service-dominant logic (Vargo & Lusch, 2004), and product-service system (Goedkoop et al., 1999). Despite the difference of terms, the main idea is to shift the focus of traditional businesses based on the design and sale of physical products to a new business orientation that considers functionalities and benefits delivered through products and services (Barquet et al., 2013; Goedkoop et al., 1999; Manzini & Vezzoli, 2003; Reim et al., 2014).

The concept for any terms strives for the same goals, and both are based on the same drivers and motivations (Baines et al., 2009). The illustration of transition from previous product concept into PSS concept is drawn in Figure 2.1 below.

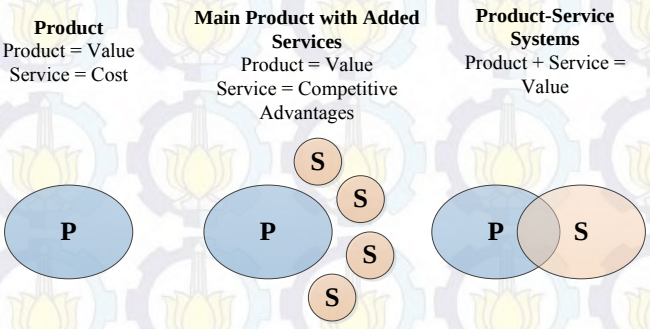


Figure 2.2 Transition from Product to Product-Service System Concept (Kryvinska et al., 2014)

Analysis from literatures result that there are three distinct categories in PSS business model implementation: product oriented, use oriented, and result oriented models (Reim et al., 2014; Tukker, 2004; Baines et al., 2009).

a. Product-Oriented

In product-oriented, in addition to selling a product, commits to deliver a service related to the product (Tukker, 2004). Generally, product is the core part whilst service is designed and provided according to the life cycle of physical product (Lujing et al., 2010). The services mostly are after-sales services to guarantee functionality and durability of the product owned by the customer such as maintenance, repair, re-use and recycling, and helping customers optimize the application of a product through training and consulting. The company is motivated to introduce a PSS to minimize costs for a long-lasting, well-functioning product and to design products to take into account product end-of-life (reusable, replaceable, recyclable) (Baines et al., 2009; Bonsfills, 2012).

b. Use-Oriented

In use-oriented model, a provider does not sell a physical product but instead makes the product available under rental or leasing agreement. In this case the company is motivated to create a PSS to maximize the use of the product needed to meet demand and to extend the life of the product and materials used to produce it. The ownership of the product is not transferred to the customer, and the risks and responsibilities for the provider increase compared to product-oriented (Tukker, 2004; Bonsfills, 2012; Reim et al., 2014; Baines et al., 2009; Lujing et al., 2010).

c. Result-Oriented

In result-oriented PSS, service can replace product to provide desired result to the customers. It consists in selling a result or capability instead of a product, for example the web information replacing directories, selling laundered clothes instead of a washing machine. Companies offer a customized mix of services where they maintain ownership of the product and the customer pays only for the provision of agreed results.

Outsourcing is also included in this type of business model (Baines et al., 2009; Bonsfills, 2012; Reim et al., 2014; Tukker, 2004).

PSS is a bundle of products and services that are capable to fulfil customers' needs in an economical and sustainable manner (Reim et al., 2014; Goedkoop et al., 1999; Tukker, 2004). In combining between product manufacturing and service, there must be a tendency or dominating activity. The relationship between services pattern and types of PSS is already defined by Tukker (2004). The fundamental idea and corresponding transition of PSS can be seen in Figure 2.2 below.

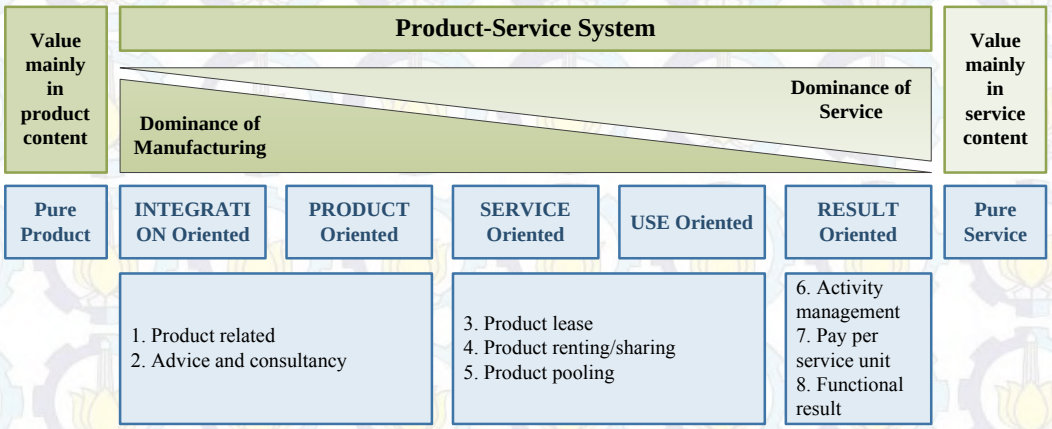


Figure 2.3 Transition of PSS – main and subcategories of PSS (Tukker, 2004)

The use of PSS will deliver new business model scheme, since the ownership of tangible product retains by the service provider, thus it changes the notion of originally manufacturing business (Kryvinska et al., 2014). In previous manufacturing system, company will not take care of tangible products after taken by customers, company only consider the manufacturing processes and the marketing. Therefore the current manufacturing system cannot match the business system of PSS. It requires redesign of manufacturing system in the company.

2.2. Make-to-Order and Make-to-Stock Manufacturing Strategies

Actually there are several manufacturing strategies such as make-to-order (MTO), make-to-stock (MTS), assembly-to-order (ATO), engineer-to-order (ETO), and others. Each system refers to different characteristics. Related to modularity and product-service system, the manufacturing strategies discussed only about make-to-order and make-to-stock system.

2.2.1. Make-to-Order

Make to Order (MTO) is a manufacturing process in which manufacturing starts only after a customer's order is received. Manufacture after receiving customer's orders means to start a pull-type operation because manufacturing is performed when demand is confirmed. MTO system offers high variety of customer specific and typically, more expensive products (Soman, 2005). MTO system is supported by zero or small inventories, agile enough to guarantee short response time. Inventories are eliminated, but customers must now wait for delivery, perhaps leading to loss of competitiveness on the part of the firm (Kaminsky & Kaya, 2007).

In MTO system products are built to specific customer requirements. The final product usually is combination between standardized and custom parts. Customers are prepared to wait in order to get a product with unique features, usually customized or highly engineered products. All activities are conditioned to achieve customer due date (Lieskovsky, 2014).

2.2.2. Make-to-Stock

Make to Stock (MTS) is a manufacturing process in which manufacturing done to anticipating demand from customers. MTS is push-type operation because the production is done before the actual order received, therefore the market that should follow the production. The MTS systems offer a low variety of producer-specified and typically, less expensive products. The competitive priority is higher fill rate (Soman, 2005).

MTS allows satisfying customer demand with existing inventory. Customer orders are then filled from existing stock, and then those stocks are replenished through production orders. Products are manufactured based on demand forecasts. In the industrialized society of mass production and mass marketing (MTS), the forecast mass production urged standardization and efficient business management such as cost reduction. This approach has the shortest lead-time from a customer perspective. Practically this type of business runs as push-type production. Most products found in department stores, groceries, clothing stores and other retail environments use the MTS approach (Lieskovsky, 2014).

2.2.3. Make-to-Order and Make-to-Stock Comparison

MTO and MTS system have contrast characteristics. There are several aspects that used as difference indicator between those systems, and the comparison can be seen in Table 2.1 below. In table 2.2 there is an illustration which shows order fulfilment process comparison between several manufacturing strategies.

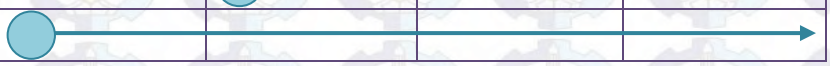
Table 2.1 Make-to-order and make-to-stock comparison

Indicator	MTO	MTS
Type of stock	Raw material	Finished goods
Break point	Planning	Stock
Type of market	Specific	Segments
Scheduling	Master scheduling, finish date	Forecast
Type of products	Cars, Air conditioning	Groceries, clothes
Type of production	Pull	Push

(Source: Lieskovsky, 2014)

From table 2.1 above, it is known that in make-to-order system the inventory is raw material because manufacturing processes has not been done yet, while in make-to-stock the inventory is finished goods. The scheduling of MTO uses master scheduling of finish date to forecast production lead time that offered to the customers, however MTS system using the demand forecast for scheduling.

Table 2.2 Product positioning strategy

	Procurement	Fabrication	Assembly	Delivery
MTS				
ATO				
MTO				
ETO				

(Source: Pujawan, 2014)

There are four popular manufacturing strategies which are Make-to-Stock (MTS), Assembly-to-Order (ATO), Make-to-Order (MTO), and Engineering-to-Order (ETO). It can be seen that in MTS system, the product is directly delivered when there is order from customers, while in MTO the product will be fabricated first and then assembled before delivered to customers. Therefore MTO has longer lead time than MTS yet it is more flexible.

2.3. Flow Process Chart

There are several methods to present and evaluate process flow; one of them is Flow Process Chart (FPC). FPC is a symbolic representation the processing activities performed on the work piece. FPC can be visualized in form of graph or table (Graham, 2004). Graph is used for simple and less process while table is more detail and used for complex processes flow. FPC is used when:

- Observing physical process, to record actions and get an accurate description of the process
- Analyzing the steps in a process, to help identify and eliminate waste
- The process is mostly sequential, containing few decisions

Table of FPC is also used to analyze detail of process through 5W+1H questions and improvement suggestions, but some FPC is simplified based on condition in observed object. FPC is preferred than OPC to be used in comparing current condition with proposed improvement because the differences can be seen

more obvious. There are several standard symbols used in FPC which can be seen in table 2.3 below.

Table 2.3 FPC Symbol

Symbol	Description
	Operation
	Transportation
	Delay
	Inspection
	Inventory

(Source: American Society of Mechanical Engineers, 1947)

Table 2.4 FPC Template Sample

FLOW PROCESS CHART									SUMMARY						
Job/Department:									Actions					No	Time
									Operation						
									Transport						
Type : Material Man Machine									Delay						
Method : Present Proposed									Inspection						
Chart Start :			Chart End :						Storage						
Charted by:			Checked by:						TOTAL						
Activities	Operation	Transport	Delay	Inspection	Storage	Duration	Quantity	Distance	Analysis						Notes
									What	When	Who	Where	How		
1.															
2.															
3.															
4.															
5.															

(Source: www.dtic.mil)

2.4. Modularity

In product architecture, there are modular and integral architecture. In which Ulrich (1995) defined product architecture as the arrangement of functional elements; the mapping from functional elements into physical components; and the specification of interfaces among the interacting components. Integral product architecture refers to a complex (not one-to-one) function mapping, while modular product architecture has one-to-one correspondence between modules and functions (Eggen, n.d.; Ulrich, 1995). The different of integral and modular product architecture can be seen in Figure 2.3 and Figure 2.4 below.

Modularity is a method to simplify large number of parts or components by grouping into several groups or modules under similar criteria that can be managed independently and used interchangeably in different configurations (Boer & Hansen, 2013; Sohail & Al-Shuridah, 2011; Schilling, 2000). Modules are defined as physical structures that have a one-to-one correspondence with functional structure (Eggen, n.d.; Asan et al., 2003; Boer & Hansen, 2013). Through reconfiguration, modular product architecture is able to increase the variety of products, and also able to reduce time to market and cost by doing standardization. Modular process as well is able to increase the flexibility of company through re-sequencing and postponement (Hoek & Weken, 1998; Wang et al., 2014). In general, modularity is an organization of components which are designed independently but still function as an integrated whole.

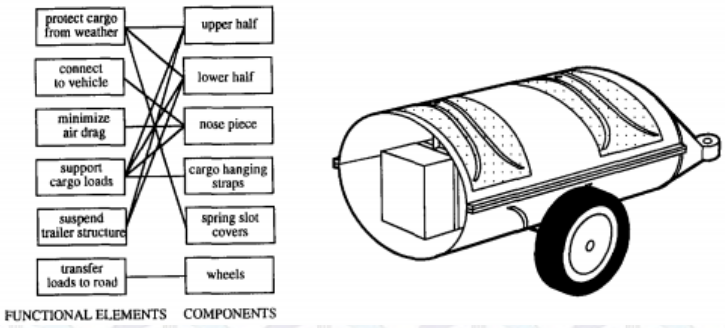


Figure 2.4 Integral product architecture of a trailer (Ulrich, 1995)

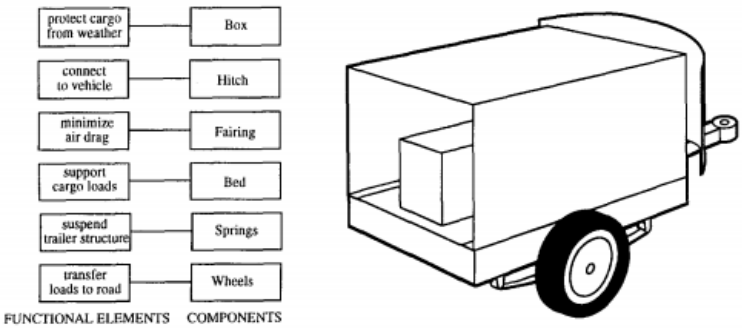


Figure 2.5 Modular product architecture of a trailer (Ulrich, 1995)

Since all systems are characterized by some degree of coupling between components, almost all systems are modular, and very few systems have components that are completely inseparable and cannot recombined (Schilling, 2000). Product architecture of modularity is distinguished from others by determining the set of standard design rules. Based on Baldwin and Clark (2000) the categories of design information are (Asan et al., 2003):

- Architecture, which specifies the part of systems and the functions;
- Interfaces, that describes how the components will fit together, connect and communicate;
- Standards, which is used to test the module's conformity to design rules and to measure the performances of one module to each other.

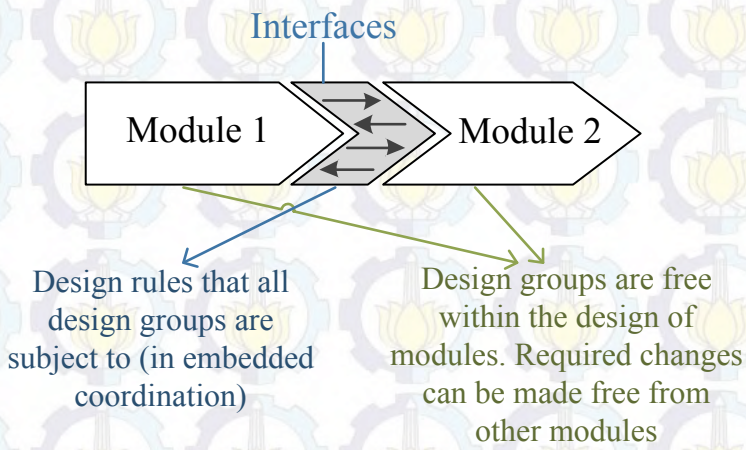


Figure 2.6 Basic Idea of Modularity (Asan et al., 2003)

The basic concept of modularity supports the idea of interdependence within and independence across modules (Figure 2.5) (Asan et al., 2003). The primary reason of increasing modularity is to enable heterogeneous inputs to be recombined into heterogeneous configuration.

There are many different ways to modularize product. Two companies manufacturing same type of product could end up with different modularized product structure, depending on the product and company strategies (Eggen, n.d.). Modularity also required integration of many divisions of the company such as the production, marketing, PPIC, and others, in which each divisions has different performance and level in supporting the modularity. Therefore modularization can be successful for a company and can be failed for other company.

Although modularization process constitutes the core, it is not enough to build a successful modular architecture design. Modularization process become more effective when there is appropriateness within the modularity analysis, modularity strategies, requirements analysis and evaluation stages (Asan et al., 2003). While studies in literature stated that integrated methodology will lead into successful modularity, which consists of requirements analysis, decomposition, composition and analysis (Kusiak, 2002; Zamirowski & Otto, 1999; Jiao & Tseng, 1999).

There are several types or methods of modularity which are: customer-based design, function-based design, and structure-based design (Asan et al., 2003). These rules define the modules that being part of products, the interactions among modules and standards for conformity to the design rules. In order to determine the most suitable modularity process, there are several considerations such as the cost, time, product type constraints, and complexity. It is also possible to use several types of modularity processes to be compared each other, but it will be time consuming. Each process must be has different characteristics (Asan et al., 2003).

2.4.1. Customer-based design

The main idea of customer-based design is to construct a model of market in terms of customer needs and allow that model to determine how to

set up the portfolio architecture (Yu & Otto, 1999). Customer needs can be related to product features whose performance targets vary between and among customers through different product uses. The distribution of market tendencies can be analyzed in order to propose portfolio architecture.

The result architecture will lead company into higher variety of products to meet different needs of customers in the market. It is also possible to use the result of this approach as input for function-based or structure-based design (Bachmann et al., 2000; Asan et al., 2003; Eggen, n.d.).

2.4.2. Function-based design

Product architecture is the mapping of product function to physical form, in which functions are the operations or activities performed by the product. In function-based design methods, the functions of components are presented systematically or schematically. The function deployment mostly based on FAST, function trees, FMEA, function structure and other function-logic diagramming methods attempt to illustrate the links among the sub-functions (Zamirowski & Otto, 1999; Wang & Nnaji, 2001).

This function-based design is also good for designing new innovative products due to the independent characteristics of components. The reason to use function-based design is its high ability in considering the customer requirements and also product functions (Bachmann et al., 2000). The function diagram is used to identify unique and common modules for a product family and modules responding to different needs for a product.

Function-based modularity is the most popular type of modularity, which is used because of the simplicity but very suitable for complex product. Based on Al-bdour (2014), there are four types of function-based modularity as follows:

- Slot Modularity

  This type of modular allows a standard devise to perform multiple functions based on the number of parts that can be assembled to this module consecutively.

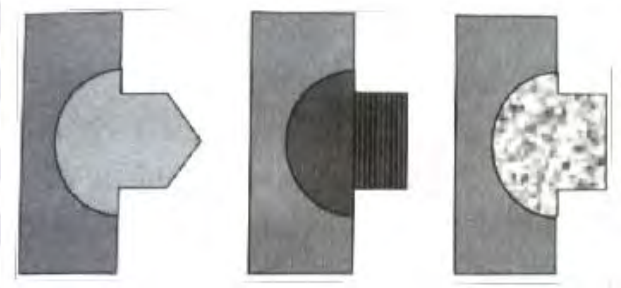


Figure 2.7 Slot Modularity (Al-bdour, 2014)

- Bus Modularity

  Bus modularity allows a standard devise to be upgraded in terms of function and performance due to the inclusion of number of different parts in a standard interface.

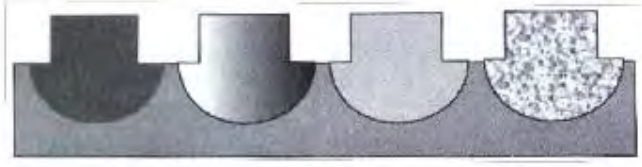


Figure 2.8 Bus Modularity (Al-bdour, 2014)

- Sectional Modularity

  Sectional modularity allows standard device to do multiple jobs through the addition of several number of different parts which are attached or chained permanently using an interface.

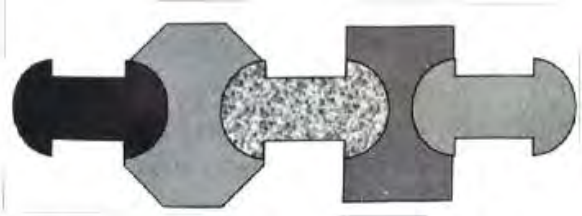


Figure 2.9 Sectional Modularity (Al-bdour, 2014)

- Mix Modularity

  Mix modularity is further development of sectional modularity in which the addition parts are attached together through a module webs instead of chain.

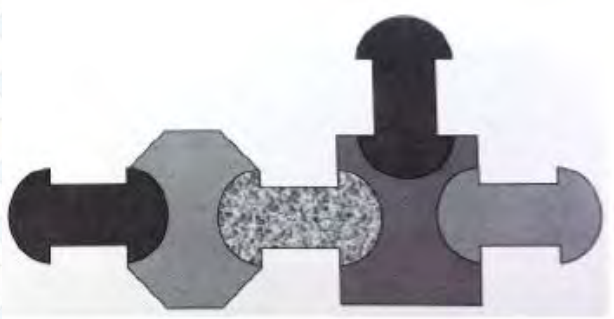


Figure 2.10 Mix Modularity (Al-bdour, 2014)

2.4.3. Structure-based design

This structure is focused on structural elements of a product and relationship among them. Generally there are two most famous software; which are the design structure matrix and task structure matrix. The aim of this method is to achieve a structure in which the units are highly interconnected but largely independent to other units. This algorithm transforms a component-component interaction matrix into modularity matrix

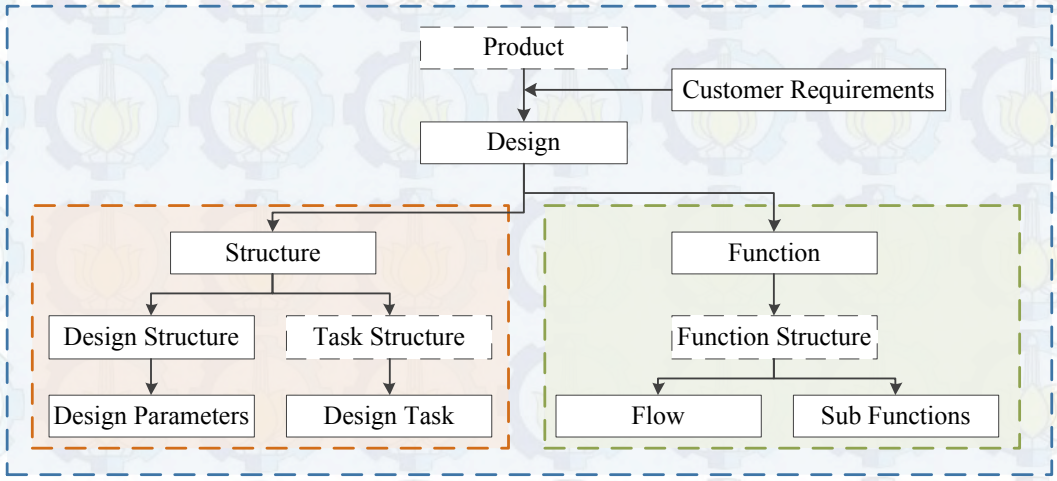


Figure 2.11 Hierarchy of customer-, function-, and structure-based design (Asan et al., 2003)

2.5. Modular Function Deployment

Modular Function Deployment (MFD) is a systematic method to aid the design of modular product. MFD is the general concept which consists of five

main steps and each step might consist of more specific tools. The steps of MFD are (Österholm et al., 2002):

1. Technical Solution Analysis

   The most popular way in clarifying customer requirements is by using Quality Function Deployment (QFD). Customer requirements will be translated into technical solutions through what-how relationship of QFD (Figure 2.11).

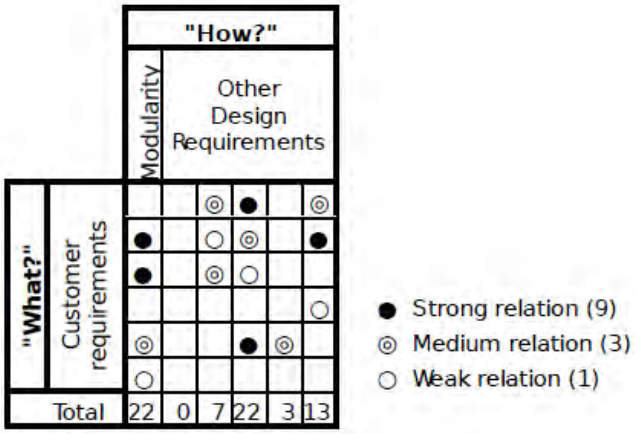


Figure 2.12 QFD Matrix (Eiden, 2013)

2. Function Analysis

   Functional structure or functional hierarchy is deployed in the second steps to ease the analysis and selection process of technical solutions. In order to form an architectural representation of technical solutions, Function Tree is generally used. Figure 2.12 and 2.13 below show the sample of function tree.

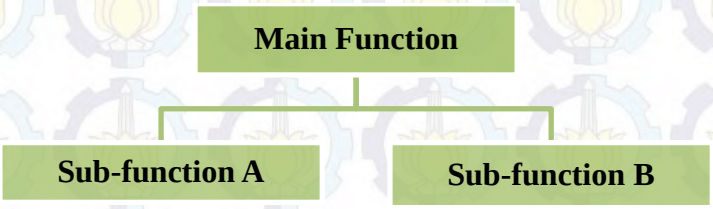


Figure 2.13 Simple Function Tree (Eiden, 2013)

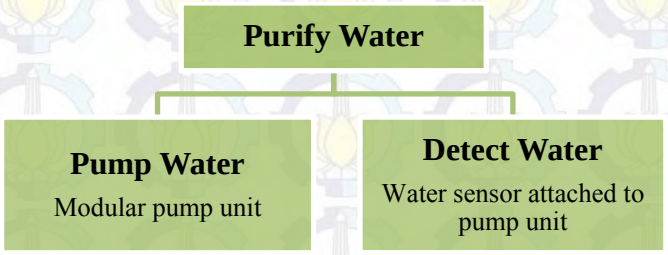


Figure 2.14 Function Tree with Technical Solutions (Eiden, 2013)

In functional tree all required and optional functions to the process are mapped in a way that the connections between sub functions can be clearly established. The available technical solutions to achieve the functions also can be analyzed through the second type of functional tree (Figure 2.13). As there are multiple options for technical solutions, the various solutions should be evaluated at this stage to determine the most suitable solution from technical point of view. The technical solutions are company's capability to be performed in the product, thus the selection of technical aspect requires discussion with the company or related expertise.

3. Generate Concepts

   The modular concept is built through Module Indication Matrix (MIM). MIM appears similar to QFD matrix, instead of mapping customer requirements against technology solutions; MIM maps module drivers against functions (Figure 2.14). Module drivers are used as decision-making tool when defining modules.

Module drivers \ Technical solutions		Technical solution 1	Technical solution 2	Technical solution 3	Technical solution 4	Technical solution 5	Technical solution 6	Technical solution 7	Main Drivers
Development & Design	Carry-over	3			9	9		3	24
	Technology evolution		3	9		9			21
	Product plan		1	3			3		7
Variance	Different specification	3				3			6
	Styling		3		3		9		15
Manufacturing	Common unit	9	9				9	9	36
	Process & organization	3	1			3			7
Quality	Separate testing	3		3					6
Purchase	Supplier avaliability				1			9	10
Aftermarket	Service & maintanence		3			9			12
	Upgrading			1		3		9	13
	Recycling				3			1	4
	Dominating functions	21	20	16	16	36	21	31	

Figure 2.15 Example of Module Indication Matrix
(Granstrom & Hagman, 2012)

In MIM there are three score classifications which are: 9 for strong relationship, 3 for medium relationship, and 1 for weak relationship. There are twelve module drivers according to Ericsson & Erixon (1999) which are (Granstrom & Hagman, 2012):

Development and design

- Carryover : Parts or sub-systems that most likely will not be exposed to design changes during the life of product should form a module
- Technology evolution : Parts or sub-systems that are likely to undergo changes as result of changing demands or technology shift should form a module
- Product plan : Parts or sub-systems that the company consciously will develop should form a module

Variance

- Different specification : Parts or sub-systems that create variance and different specification should form a module

- Styling : Parts or sub-systems that create visual and virtual variance should form a module

Manufacturing

- Common Unit : Parts or sub-systems that can be used in the entire product family should form a module
- Process and organization : Parts or sub-systems that have similar production or installation process should form a module

Quality

- Separate testing : Parts or sub-systems that have potential to undergo separate functional testing should form a module

Purchase

- Supplier availability : Parts or sub-systems that exist at sub-suppliers and vendors should form a module

Aftermarket

- Service and maintenance : Parts or sub-systems that demands recurring service and maintenance should form a module
- Upgrading : Parts or sub-systems that can be upgraded should form a module
- Recycling : Parts or sub-systems that should be easily recyclable should form a module

4. Evaluate Concepts

   This stages is to synthesize or clustering components into modules, and analyze the module candidates against each other and also against previous condition. In this stage the interfaces between modules also need to be defined, because interface also plays major role in production time required, if the interface is too complex it can be considered as negative impact on product (Granstrom & Hagman, 2012).

5. Improve Each Module

   The goal of this last stage is to improve the modular attributes of the module, or as the final fixation of the module candidate chosen. Any

further analysis such as production lead time and cost analysis also can be performed in this stage (Eiden, 2013).

2.6. Periodic Review Inventory

Periodic review method is used for uncertain demand condition. In this method, the stock level is examined at specific time, and the stock is ordered as much as the difference between target level and stock at that time (Waters, 2003). In inventory management basically there are two main problem which are the interval between order or checking period and the target level of stock. Since it is a periodic review, inventory checking is done regularly during certain period which is named T. T could be every year, every month, every week, or even every day based on the company system. In periodic review countable items is preferable because the stock should be counted one-by-one. To find stock level there is some calculations that should be done, the formula is provided below.

$$SS = Z \times \sigma \times \sqrt{(T + LT)} \quad (2.1)$$

$$TSS = D \times (T + LT) + SS \quad (2.2)$$

$$Order\ Quantity = TSS - Stock\ on\ Hand - Stock\ on\ Order \quad (2.3)$$

In which:

SS = Safety Stock

Z = Z-value of desired service level (1-α)

σ = Standard deviation of demand

T = Inventory checking period/order period

LT = Inventory order lead time

D = Average demand

TSS = Target Safety Stock

2.7. Previous Research

The topic of modularity in this research is also discussed in several researches. The comparison of this research with previous research can be seen in table below.

Table 2.5 Research Comparison

Parameter	Previous Research		Current Research
Type	Undergraduate Research	Master Thesis	Undergraduate Research
Author	Matti Eiden	Nayef S. Al-Bdour	Viona Claresta
Year	2013	2014	2015
Title	Modular Product Development Literature Review and Case Study	Integrated Product Development Methodology Using Dual Mode QFD and Functional Hierarchy Applied to a Real Case Implementation	Modular Product Development Towards Product Service System (PSS) Implementation at PT. X
Object	Container	Militarised All-Terrain Vehicle (MATV)	Commercial Vehicle Construction
Methods	Modular Function Deployment, Function Structure Heuristics, Module Indication Matrix, Discussion, Design Structure Matrix	QFD, AHP, Kano Model, Integrated Dual Mode QFD, Design Drivers, Function Hierarchy, Architectural Analysis, Interface Matrix, Design Structure Matrix	Modular Function Deployment, FGD, Module Interaction Matrix, Design Structure Matrix
Output	Modular product classification of container	Integrated advanced product development methodology, Modular product design of MATV	Modular product classification of commercial vehicle construction

CHAPTER 3
METHODOLOGY

This chapter informs about the sequences of activities that done in this Final Project and the methodology of study in order to find solution of the problems. There are flowchart and also flowchart description about the steps.

3.1. Flowchart

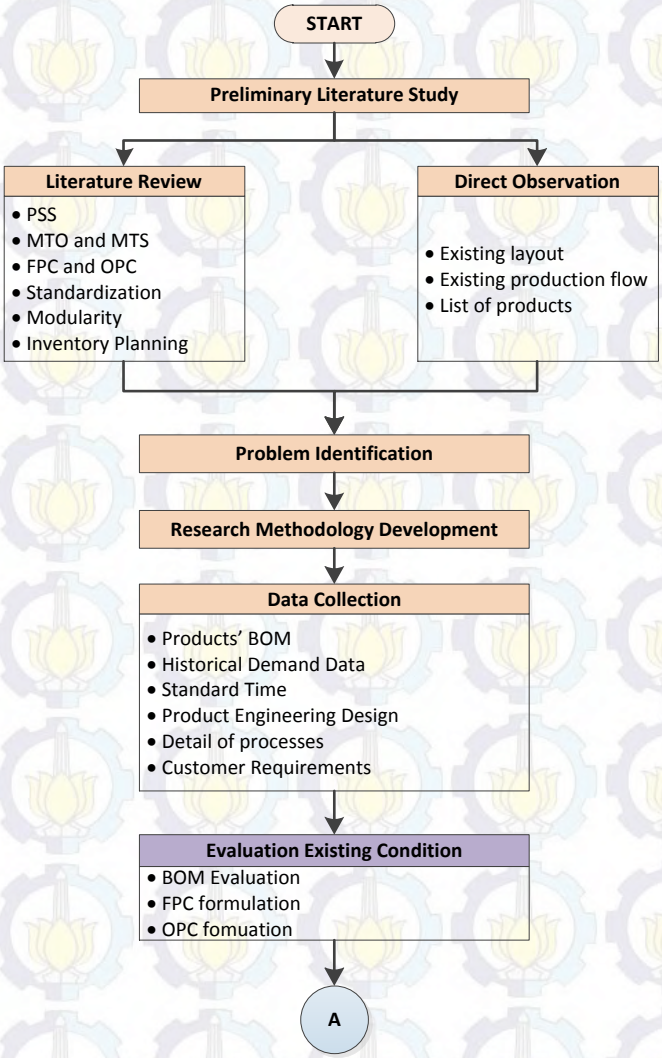


Figure 3.1 Final Project Methodology Flowchart

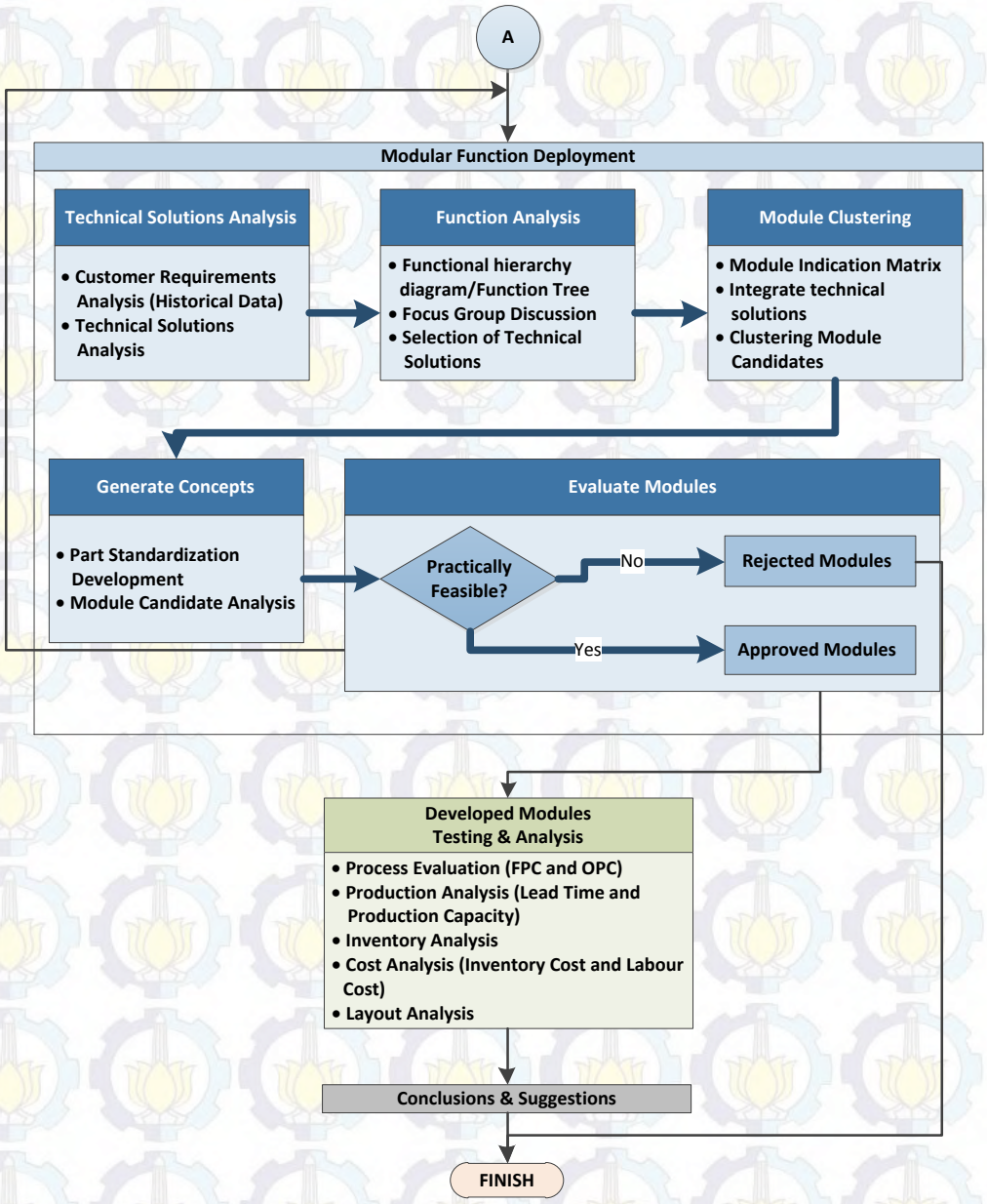


Figure 3.2 Final Project Methodology Flowchart (con't)

3.2. Flowchart Description

There are five stages in the research methodology, the first one is problem identification; then evaluation of existing conditon; the third is modular function development; and then developed modules testing and analysis; and the last is conclusion.

3.2.1. Problem Identification

The problem identification stage starts with preliminary literature study to get brief information and knowledge of possible problems in the company. Then deeper information is searched by doing literature review and also direct observation. Direct observation is done to get clearer vision of the problem happened in the company, therefore during direct observation there are several data that being observed such as the existing production system, existing layout, and list of products. While literature review is done on several topics related to the problem such as Product-Service Systems, Make-to-Order and Make-to-Stock System, and Modularity. After the observation in the company, there is problem identification to formulate and synthesise the core of problem that should be solved, and then related data to the problem is collected such as the product's BOM, standard time, engineering drawing, historical demand data, detail of processes, and customer requirements. The customer requirement is analyzed based on previous demand data from customer.

3.2.2. Evaluation of Existing Condition

The second stage consists of evaluation of existing condition as the input for further analysis, thus there are BOM evaluation and also Flow Process Chart (FPC) formulation. BOM evaluation and FPC formulation is used to ease the further analysis on parts interaction. BOM table will show detail of components used per part, while FPC shows the detail manufacturing steps or procedures.

3.2.3. Modular Function Deployment

The MFD consists of five stages which are technical solutions analysis, function analysis, module clustering, generate concepts, and module evaluation. The technical solutions analysis is done by analyzing technical requirements from the company. Once the concept is done, the actual technical solutions are formed in next stage by listing all possible alternatives.

Function analysis is done to ensure that the module developed is by using function-based design. In the function analysis, function tree diagram is built to give another point of view for the functions of product. Function tree also provide interaction mapping between functions and technical solutions. But earlier there is main function deployment to determine the main functions of product.

Modular clustering consists of developing Module Indication Matrix (MIM) and integration of technical solutions or clustering. The MIM will assist in recognizing potential module candidates. Instead of mapping customer requirements with technical solutions like QFD, MIM maps module drivers against main functions. Therefore there is modular driver analysis to determine the score of interaction between drivers and main functions. MIM shows the functions and module drivers with highest score, from those scores and pattern, the modules are being clustered.

Generate concepts is the process to create the modules design. It starts with develop standardized part, and then the modules. The results are several module candidates, which only the brief illustration since the candidates will be analyzed through FGD to determine the feasibility.

When all module candidates and standardized parts already designed, there is module evaluation. The module evaluation is done from Focus Group Discussion with production and design department of the company. The design should be considered by parties from company to consider the practical reasons. In FGD there is decision to determine whether the module candidate is feasible or not. If it is feasible, the module candidate will be assessed in further testing and analysis, meanwhile if it is not feasible the module candidate will be rejected.

3.2.4. Module Testing

After the modules and production system alternative is done, there feasibility and suitability test to solve the problem. The first analysis is process analysis by recreate the FPC and OPC of proposed system. The second one is production analysis which consists of lead time analysis and

production capacity analysis. The lead time is compared between current system and combination of alternatives or proposed system. Lead time comparison is done to know the gap of improvement. The new production capacity is also calculated. Modularity concept is about combining Make-to-Order and Make-to-Stock system, thus the company will have additional inventory. Therefore there is inventory analysis to calculate the minimum stock required and the scheduling. This inventory and lead time will also affect from cost point of view. There is cost analysis to briefly compare the cost of proposed system and the saving that company may gained. The last is layout analysis to calculate the additional required space from implementing new system.

3.2.5. Conclusions

Finally from the calculation and analysis that already done in previous stages, the important points are concluded to answer the objectives of the research. The things unanswered are suggested for further research to enhance the research.

CHAPTER 4
EVALUATION OF EXISTING CONDITION

This chapter consists of company overview, data collection of the existing condition in the company and continued by the analysis of the condition. The data and analysis is used as the evaluation of existing condition and later will be used to compare with improvement suggestion.

4.1. Company Overview

PT. X was established in 1980s in the area of commercial vehicle construction. Almost 30 years later company has established itself as the market leader in the aluminium box sector in Indonesia.PT. X is committed in providing a standard of exceptional quality that exceeds customer expectation. In 2012, the company inaugurated its modern, fully equipped facility to reinforce the commitment to the market and in terms of research and development. Along with the new facility a new strategy evolved - this was diversify into products that would enable PT. X to meet its customers' complete needs for different vehicles, material and customized designs. Moreover PT. X uses Japan Standard Aluminium to provide high quality products for the customers.

4.1.1. Plant Layout

PT. X consists of three main halls which are hall A, B, and C. By implementing product layout, the workstations are classified based on the parts or sub-assembly produced, such as frame workstation, roof workstation, box assembly workstation, and others. There are also several storages based on the raw material or parts stored which are the aluminium storage, plate storage, iron storage, etc. Hall A and B are the main hall to produces aluminium box, while Hall C commonly used for wood truck or additional workstation during high demand period. The plant layout of Hall A, B, and C can be seen in Figure 4.1 below.

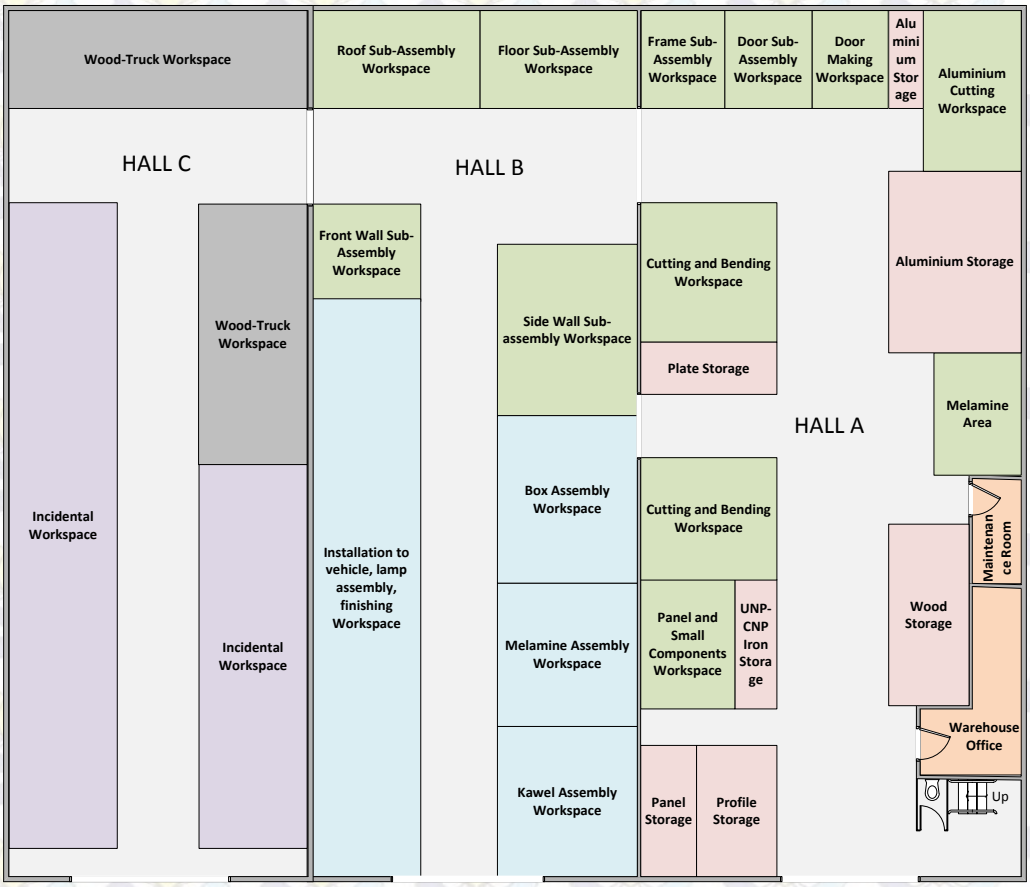


Figure 4.1 Plant Layout of PT. X

4.1.2. Products

PT. X produces commercial vehicle construction, the products can be defined as two types which is standard size or modified. The standard product uses general dimension, therefore the lead time is faster. While modified products uses new dimension or characteristics of products which are defined by customers. Standard product itself consists of several types based on the vehicle which are the 4-wheels vehicle, 6-wheels vehicle, and 10-wheels vehicle. The list of standard products for 4-wheels product can be seen in Table 4.1 below.

Table 4.1 List standard product of PT. X

No	Product	Vehicle Type	Size (cm)			Picture
			L	W	H	
1	Aluminium half box	4-wheels	197	162	106	
2			262	170	123	
3	Aluminium full box	4-wheels	215	156	139	
4		6-wheels	550	250	230	
5	DOC	4-wheels	215	156	139	
6		6-wheels	550	250	230	
7	Moko	4-wheels	215	156	139	
8		6-wheels	550	250	230	
9	Employee Transportation	4-wheels	215	156	139	
10		6-wheels	550	250	230	
11	Supper Wooden Tailgate Truck	6-wheels	435	200	150	
12		10-wheels	730	260	260	
13	Aluminium Composite Box	4-wheels	197	162	106	
14			252	170	123	
15	FRP Composite Dry Box	4-wheels	215	156	139	
16		6-wheels	550	250	230	

Table 4.1 List standard product of PT. X (con't)

No	Product	Vehicle Type	Size (cm)			Picture
17	FRP Composite Cool Box	4-wheels	215	156	139	
18		6-wheels	550	250	230	
19	Vertical Box	4-wheels	310	180	185	
20		10-wheels	980	250	250	
21	Wing Box	6-wheels	740	250	250	
22		10-wheels	980	250	270	
23	Drop-side Aluminium Door	4-wheels	310	180	60	
24		10-wheels	990	250	100	
25	Drop-side Aluminium Door	4-wheels	310	180	60	
26		10-wheels	990	250	100	
27	Laad Truck	4-wheels	310	180	70	
28		10-wheels	990	250	210	
29	Dump Truck	6-wheels	360	200	80	
30			380	200	120	
31	Flat Deck	4-wheels	250	170	-	
32		10-wheels	750	250	-	

Table 4.1 List standard product of PT. X (con't)

No	Product	Vehicle Type	Size (cm)			Picture
33	Gallon Rack	4-wheels	260	170	120	
34		6-wheels	425	200	180	
35	Iron Truck	6-wheels	435	200	150	
36		10-wheels	730	260	260	

The standard products above can be modified based on customers' preference in certain factor such as the size, material, and other details. Therefore, totally PT. X has more than 72 products.

4.2. BOM Table Evaluation

The product observed in this research is 4-wheels product. To develop standardization and modularity, the differences and similarities among various products should be compared.

Modularity is developed on the 4-wheels product, in which there are 15 types of product. Those types of products are classified into similarity classification as illustrated in figure below. Based on Figure 4.2 below, it can be seen that generally there are two streams of component type which are aluminium components and composite components. Therefore it is not necessary to compare all bill of material of products but two types.

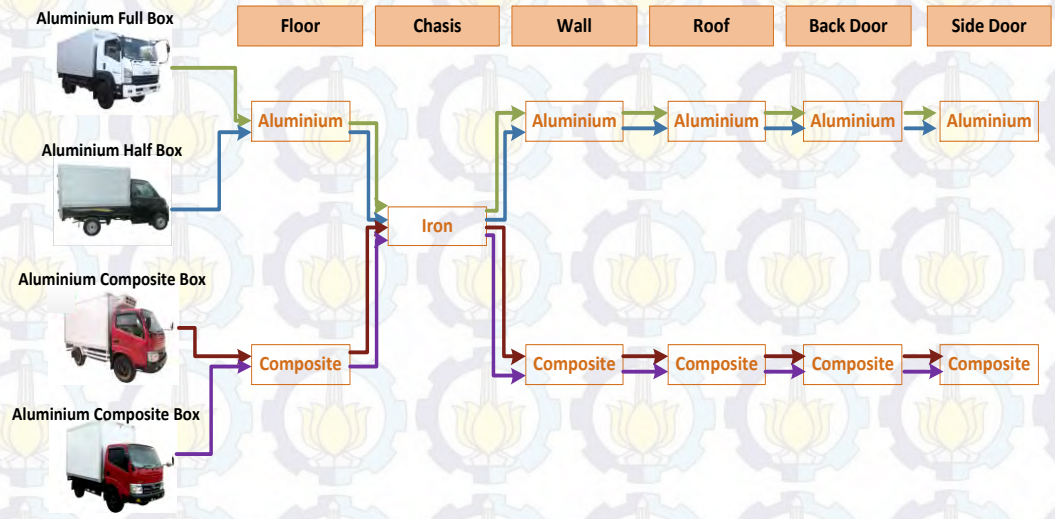


Figure 4.2 Component Classification of 4-wheels Product

Table 4.2 4-Wheels Aluminium Full Box BOM Table

NO	Code	Item Name	Unit	Material QTY	Dimensions (mm)
1	AV-01-POT	AV LANTAI POT	BT	12.00	2975
2	AV-05-POT	AV KUSEN SAMPING POT	BT	2.00	1665
3	AV-06-POT	AV KUSEN ATAS POT	BT	1.00	1740
4	AV-09-POT	AV KUSEN BAWAH (B) POT	BT	1.00	1740
5	AV-10-POT	AV DINDING STRIP POT	BT	9.00	1680
6	AV-12-POT	AV ANGIN ANGIN POT	BT	1.00	1680
7	AV-13-POT	AV ALAS POT	POT	1.00	1740
8	AV-03-POT	AV SIKU ATAP POT	BT	1.00	1740
9	AV-14-POT	AV TIANG POT	BT	2.00	1615
10	AV-19-POT	AV KELILING ATAP POT	BT	2.00	3048

To be used in further analysis, Bill of Material from standard product has to be compared with non-standard product. The comparison will result list of products which are same for both standard and non-standard product for 4-wheels vehicle, and next the standardization of product can be deployed. BOM of non-standard product (composite) is provided in Table 4.3 below.

Table 4.3 4-Wheels Composite BOM Table

NO	Code	Item Name	Unit	Material QTY	Dimensions (mm)
1	AV-14-POT	AV TIANG POT	BT	2.00	1615
2	AV-19-POT	AV KELILING ATAP POT	BT	2.00	3048
3	AV-19-POT	AV KELILING ATAP POT	BT	2.00	1750
4	AV-20-POT	AV LIS ATAP POT	BT	2.00	3000
5	AV-20-POT	AV LIS ATAP POT	BT	2.00	1448
6	AV-30-POT	AV LIS PINTU BARU	BT	1.00	0795
7	AV-18-POT	AV FRAME POT	BT	4.00	1448
8	AV-18-POT	AV FRAME POT	BT	3.00	1635
9	ST.BUNP. 65	UNP 65 X 42 X 5 X 6 M	LJR	1.00	-
10	ST.BUNP. 50	UNP 50 X 38 X 5 X 6 M	LJR	3.30	-

Bill of material from standard and non-standard product shows the similarities and differences of material, as exemplified in tables above the components with shaded colour are the similar components for both product. The similarities is shown from the item name, quantity and unit. To ensure that the materials are exactly same, it is proven by the code of material and dimensions since different material will have different code and although it use same material with different dimension will not be consider. The complete bill of material is attached in Appendix A and B.

The components listed in tables above are the components used for 4-wheels standard and non-standard box. From the Bill Of Material, it is known that standard products requires 141 types and 1814 units of component while non-standard products requires 135 types and 1507 units of components. The calculation of total number of components is done by considering that any component that has unit of meter, kilogram, and litre is calculated as one unit of component. From the comparison, it is known that there are 93 types of components which are used in both products.

4.3. Process Chart Evaluation

In process chart evaluation there are two types of chart that will be used which are Flow Process Chart and Operation Process Chart. Flow Process Chart (FPC) is used to analyze existing flow because FPC graphically displays every step of a unit of product or material including the initial condition up to the finish condition and the movement, in other way it could be said that FPC provides more

specific information. Operation Process Chart (OPC) is used to give general overview of production process, so the main objective is to illustrate the production flow.

There are several main process classified in FPC which are operation, transportation, delay, inspection and inventory. The complete FPC is provided in Appendix D.

SUMMARY			DETAIL							
	No	Time (min)	Job : FRAME SUB-ASSEMBLY (Rakit Kusen)							
Operation	8	33.22								
Transportation	0	0.00								
Delay	0	0.00	Type: ■ Material □ Worker □ Machine						Chart No : 2 of 11	
Inspection	2	4.58	Method: ■ Present □ Proposed						Date : January 2016	
Inventory	1	0.00	Chart Start :	Components					Created by : Viona Claresta	
Total	11	37.79	Chart End :	Frame Sub-Assembly					Checked by : PT Adicitra Bhirawa	

Activity	Operation	Transportation	Delay	Inspection	Inventory	Operation Duration (sec)	Moving Duration (sec)	Delay Duration (sec)	Material	Equipment
Preparation						343.27				
Arranging aluminium plate						247.51			AV Kusen Samping Pot (2), AV Kusen Atas Pot (1), AV Kusen Bawah Pot (1)	
Measurement						96.67				Waterpass, measurement meter
Drilling						105.84				Hand drilling machine
Attaching bolts and nuts						77.04				
Inspection						262.52				Waterpass, measurement meter
Drilling (small holes), 4 sides @5 holes						185.75				Hand drilling machine
Drilling (big holes), 4 sides @5 holes						134.35				Hand drilling machine
Attaching bolts and nuts						532.4				
Inspection						12.14				Waterpass, measurement meter
Inventory										

Figure 4.3 Flow Process Chart of Frame Sub-Assembly

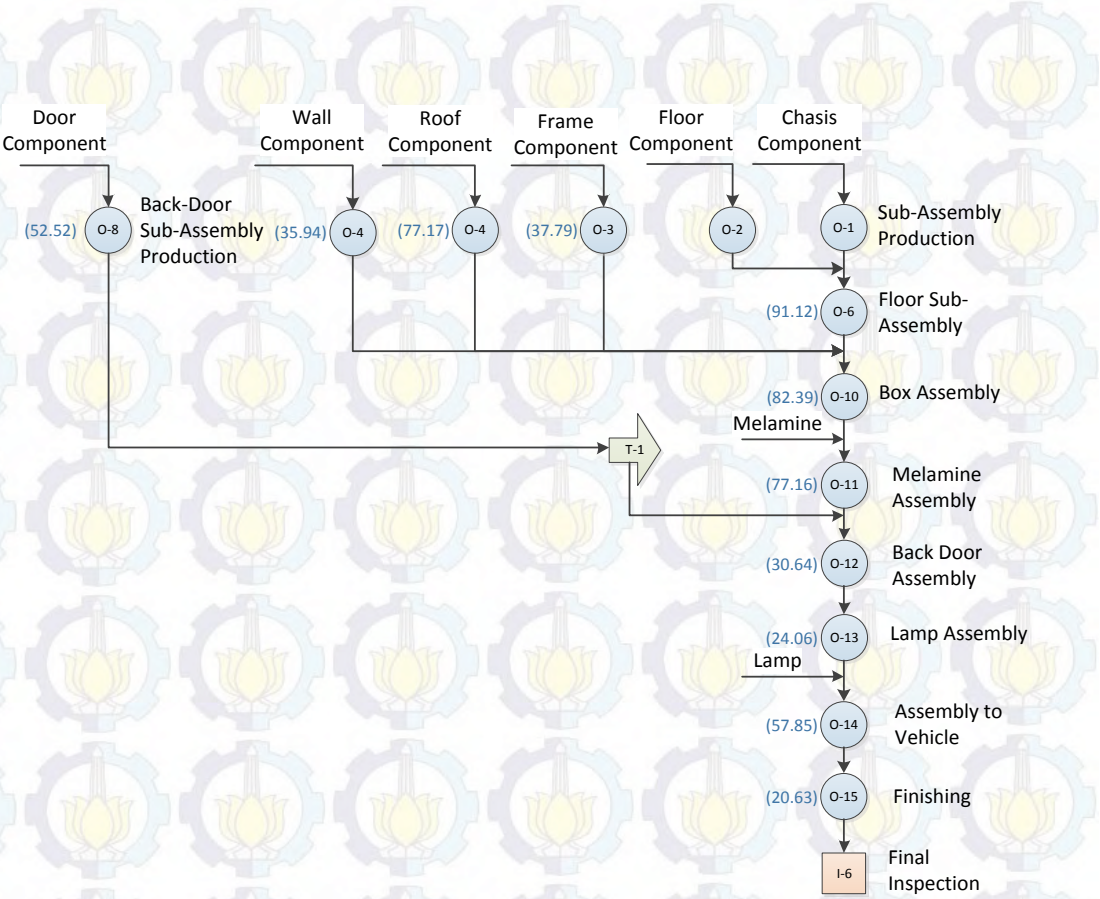


Figure 4.4 OPC of Standard Aluminium Box

Table 4.4 Production Time Recapitulation

No	Process	Duration (min)					Total	P/S	Lead Time
		○	⇨	D	□	▽			
1	Floor Sub-Assembly Production	89.95	0.70	0.00	0.47	0.00	91.12	P	91.12
2	Frame Sub-Assembly Production	33.22	0.00	0.00	4.58	0.00	37.79	P	
3	Front Wall Sub-Assembly Production	35.52	0.00	0.00	0.42	0.00	35.94	P	
4	Roof Sub-Assembly Production	76.45	0.00	0.00	0.72	0.00	77.17	P	
5	Door Sub-Assembly Production	42.13	2.03	0.00	8.36	0.00	52.52	P	
6	Box Assembly	76.35	3.90	0.00	2.14	0.00	82.39	S	82.39
7	Melamine + Roof Assembly	65.15	7.01	0.00	5.00	0.00	77.16	S	77.16
8	Back-Door Assembly	24.36	2.94	0.00	3.33	0.00	30.64	S	30.64
9	Lamp Assembly	18.22	2.50	0.00	3.33	0.00	24.06	S	24.06
10	*Kawel* Assembly	50.68	2.18	0.00	5.00	0.00	57.85	S	57.85
11	Finishing	17.60	0.00	0.00	3.04	0.00	20.63	S	20.63
Total (min)									**383.84**
Total (hours)									**6.39738**

The total production time of an aluminium standard full box product can be known by recap all the FPC duration as in Table 4.4 above. The longest production duration is floor sub-assembly, and the shortest is finishing process. In calculating lead time of a product, parallel and series production system should be considered. In table above P refers to parallel and S refers to series, thus in the parallel processes, the lead time is equal to the largest production time among processes. The lead time for one product is 383.84 minutes or equal to 6.39 hours.

CHAPTER 5
MODULARITY DEVELOPMENT

This chapter will discuss about part standardization and modularity development, thus there are customer requirements analysis, technical solutions analysis, Module Indication Matrix (MIM), standardization development, module candidate analysis, and module specifications.

5.1. Technical Solutions Analysis

Technical solutions show the responses from company to the customer requirements. Customer requirements trigger the technical responses and from technical response, related components are determined. The technical responses are obtained through interview and discussion with Marketing Department from the company since the customer requirement cannot be received through questionnaires. In total there are 4 people in Marketing Department, but the information are gathered from 3 people with medium-high experience in the department. The experience is measured by the duration of work in PT. X which are more than 5 years. The company had never done specific survey to their customers, but these customer requirements are based on the experience during serving customers.

The technical responses listed below are the modes requirements requested by customers and also the basic quality provided by company. Therefore the customer requirements are separated into basic expectations, satisfiers and delighters similar with Kano Model classifications. The classifications are shown by different colour in table below. Actually those classifications do not have high impact yet only become consideration in modular development.

Table 5.1 Technical Responses Breakdown

Customer Requirement	Technical Response	Components
Strong from external interference	Non-corroded material	Wall, roof, door
	Solid material	Wall, roof
Water resistant	Waterproof material	Wall, roof
	Waterproof joint	Wall, roof (Rivet, silicon glue)
Good Air Circulation	Number of air circulation holes	Wall, Back Door
	Diameter of holes	Wall, Back Door
	Exhaust system	Wall, Back Door, Roof
Strongly connected to vehicle	Strong joint between chassis and vehicle	Chassis
Easy to access load	Large and open-wide door	Back door
	Located in front part of box	Side-door
Light-weight	Mass of material	Wall
Cheap	Use another cheaper material as alternative	Wall, Door
Strong to withstand heavy loads	Use higher tensile strength material	Chassis, floor

Basic Expectations	Satisfier	Delightful

5.2. Function Analysis

Function analysis is very important in module development since the constructed modules are function-based module. There are two main steps in function analysis which are main function analysis of product and function tree analysis. The function analysis is done through analysis and discussion with Production Department supervisor. The discussion is done since the supervisor is expertise to deeply analyze the classifications, and also to ensure the result of analysis is in accordance with real condition of product and company.

5.2.1. *Product Main Function Analysis*

In order to analyze the modular part, the main function of product should be listed and the components should be grouped into one-to-one mapping. The main function deployment of commercial vehicle construction is illustrated in figure below.

From main function deployment below, it is known that there are eight main different functions of commercial vehicle construction, which will be related into technical responses to classify the characteristics and requirements for each function. The module that will be developed is combination of the main functions.

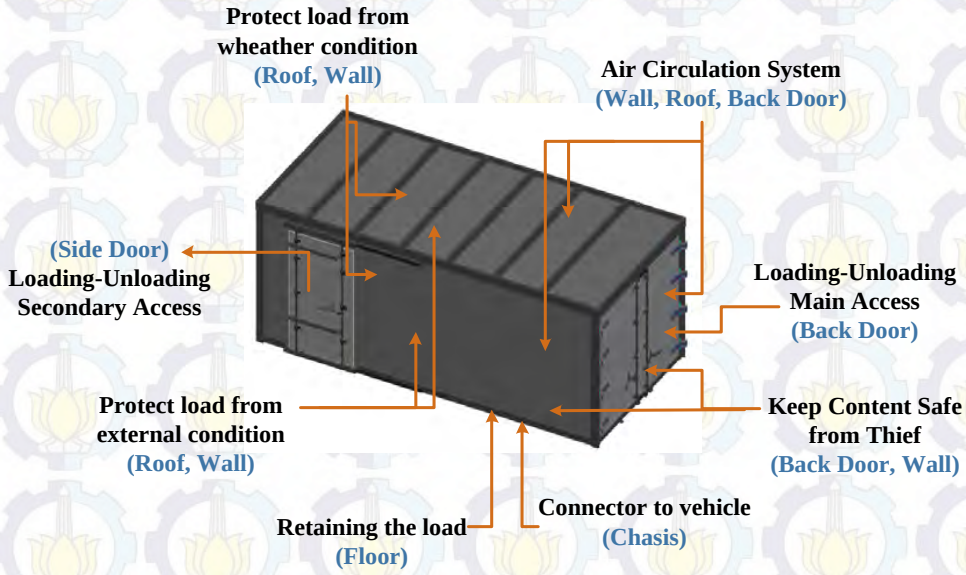


Figure 5.1 Product Main Function Deployment

5.2.2. *Function Tree Analysis*

Function tree analysis is used to classify the components with sub-functions into certain main functions. Function becomes the basic consideration since the module developed is using function-based design. The previous customer requirements become sub-functions which are deployed from the eight main functions, and the technical responses become detail description to obtain full compatibility with the user requirements.

5.2.2.1.Protect Content from External Condition Function

Protect load from external condition can be said as the top function of commercial vehicle construction, thus there are many sub-functions that should be achieved to fulfil requirements from the customers. The part related with this function is box wall and roof. The function tree can be seen in figure below.

At the top level, protecting content from external condition is the main function and will be achieved by having water resistant, light weight, large capacity, strong of external interfere, and cheap characteristic. Strong from external interfere means the box wall have to withstand whenever there is external forces such as collision. This is related to actual condition of box and vehicle which is likely to crash or get hit on road. Therefore wall must be constructed of non-corroded and solid material.

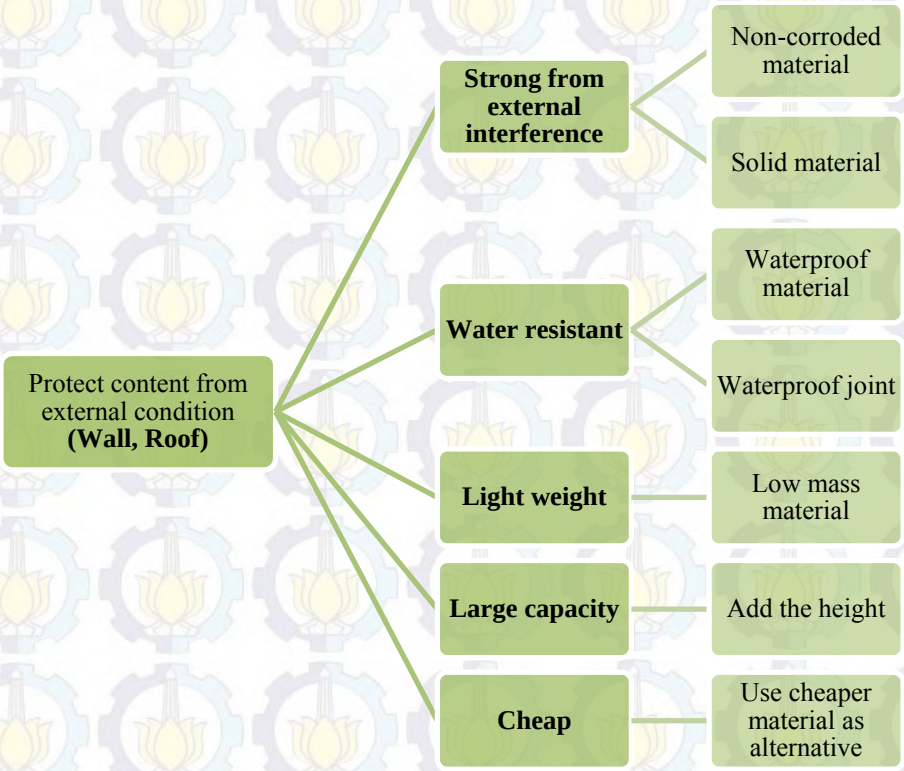


Figure 5.2 Wall Function Tree Analysis

5.2.2.2.Protect Content from Weather Condition Function

Protect load from weather condition is related with box roof and floor. Though the wall also protect load from whether but most of whether disturbance is come from upward such as the solar thermal, rainwater, lighting, etc. The function tree can be seen in figure below.

The first sub-function is strong from external interference, which is similar with the wall, but to achieve this sub-function non-corroded material is the only requirements. Previously wall should be constructed of solid material but for roof solid material is not the main requirements to fulfil, since solid material is used to retain the external force and roof does not directly interacted with external force. The following sub functions are water resistant and good air circulation. Water resistant is highly important for roof which directly interacted with rainwater. Good air circulation is also related with whether issue since the commercial vehicle construction will be exposed to hot and cold weather condition. If the air circulation is not good then the condition of load may disrupted.

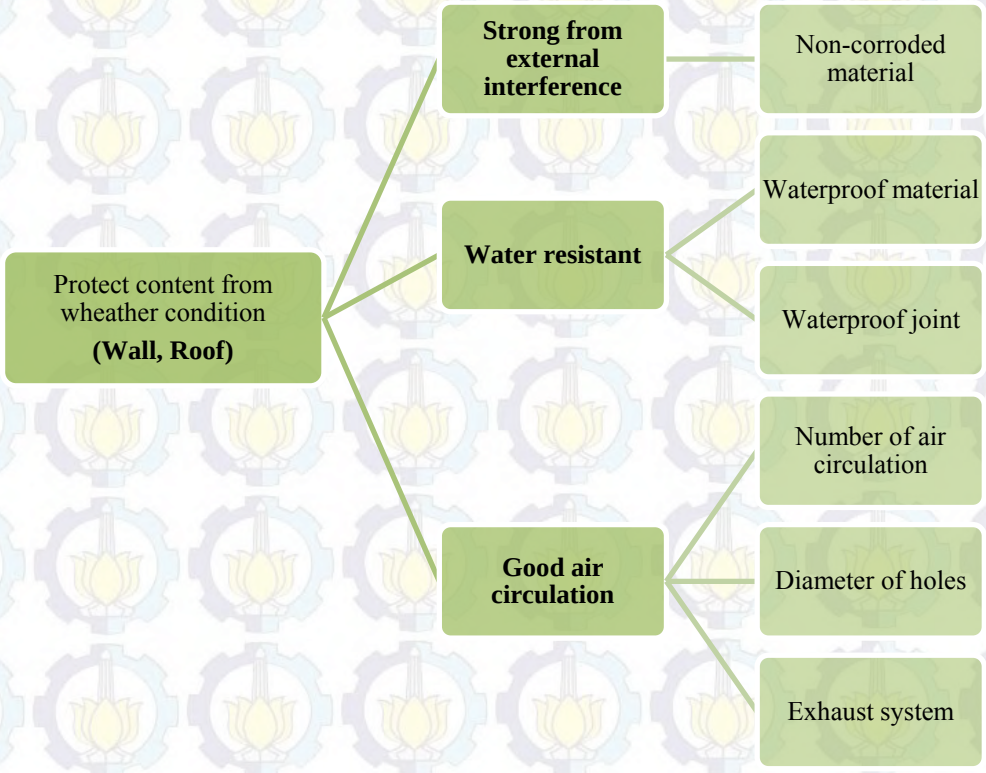


Figure 5.3 Protecting Content Function Tree Analysis

5.2.2.3.Loading-Unloading Main Access Function

Back door is the box component which responsible as loading and unloading main access. The sub-functions are; strong from external interfere, good air circulation, easy to access and cheap. Strong from external interfere characteristics are also similar with the wall, non-corroded and solid. This similarity arises because those components are both located on the side or circumference of box. Slightly different from roof which only requires non-corroded material, back door will also retain box from external forces thus solid material characteristic is required. The function tree analysis of back door can be seen in figure following.

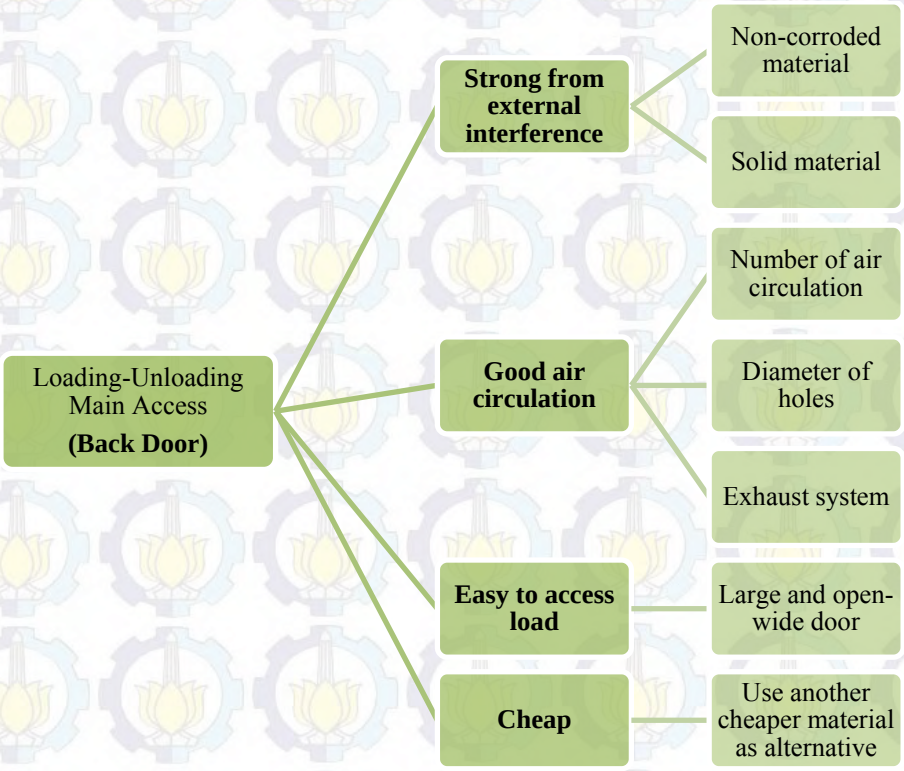


Figure 5.4 Loading-Unloading Main Access Function Tree Analysis

5.2.2.4.Retaining the Load Function

Retain the weight of content is the function of floor. There are two sub-functions that should be accomplished which are water resistant and strong to withstand heavy loads.

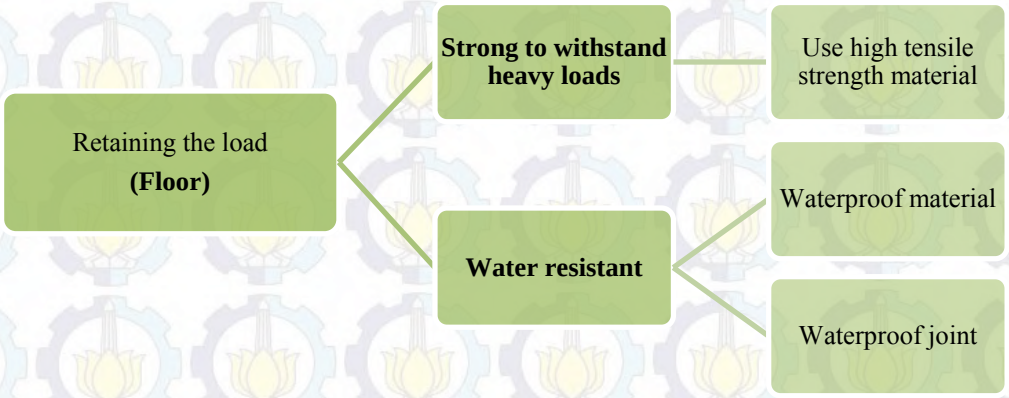


Figure 5.5 Retain Load Function Tree Analysis

Water resistant consists of waterproof material and waterproof joint, while strength to withstand heavy loads could be achieved by using higher tensile strength material. Tensile strength related to the capability of material to retain the force before the deformation happens.

5.2.2.5.Air Circulation System

Function of air circulation system is related with back door, wall and roof since there are air circulation holes in these three components. Air circulation in an enclosed object depends only on air circulation holes, therefore the sub-functions and characteristics are related to the holes. The function tree analysis can be seen in figure below.

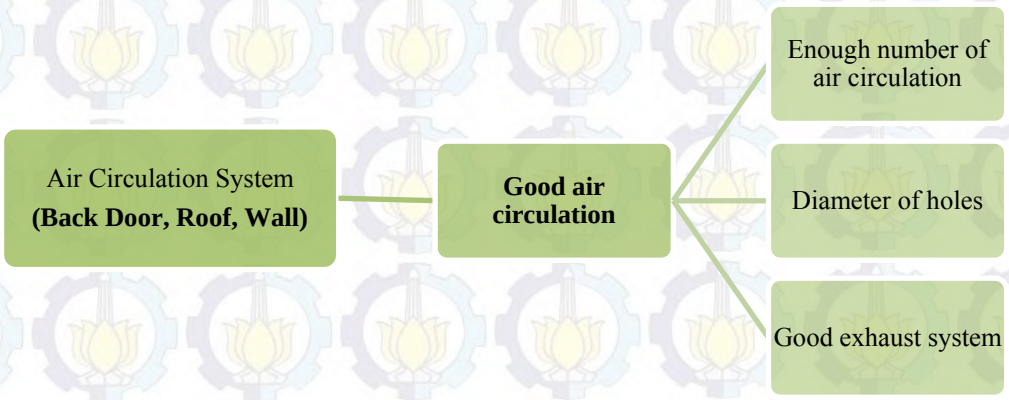


Figure 5.6 Air Circulation Function Tree Analysis

5.2.2.6.Connector to Vehicle Function

Chassis is the component of commercial vehicle construction which directly connected to the vehicle. Chassis is also the component to retain the load of content. Therefore the sub-functions are strongly connected to vehicle and strong to withstand heavy loads. The main factor in connecting chassis and vehicle is located in the joint, thus the joint of chassis and vehicle should be very strong. To withstand heavy loads, chassis is made of higher tensile strength material, even higher than the floor because actually chassis is the component that retains the load. While floor only used to largely distribute the weight.

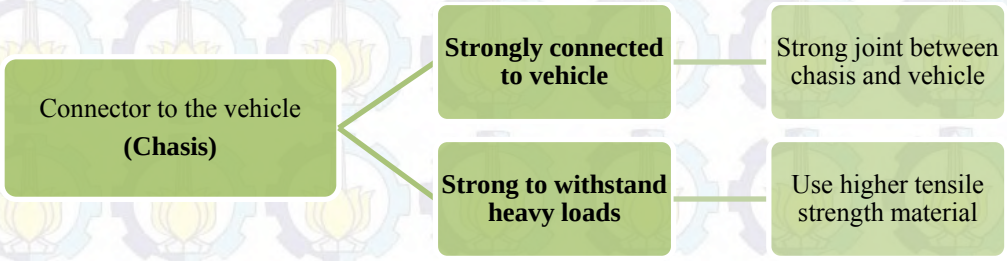


Figure 5.7 Connector to Vehicle Function Tree Analysis

5.2.2.7.Loading-Unloading Secondary Access Function

Loading-unloading secondary access is the function of side door, but actually side door is additional features to the product based on customer demand. Side door is used when the box should drop loads in several number of locations, thus it will be difficult to take related thing that may located in the deeper part of box. Because the function is as the additional loading-unloading access, side door should make user easier to access the load. Thus it is located in the front part of box wall.

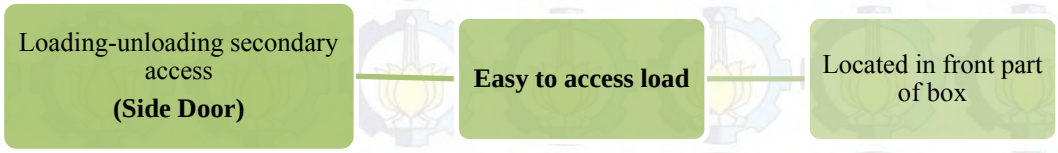


Figure 5.8 Loading-Unloading Secondary Access Function Tree Analysis

5.2.2.8.Keep Load Safe from Thief Function

Keep load safe from thief relates with back door and wall functions. Back door as the loading-unloading access should be strong enough to keep the content inside, and the wall also should be solid and strong to avoid burglary. The sub-functions and characteristics to support this function can be seen in figure below.

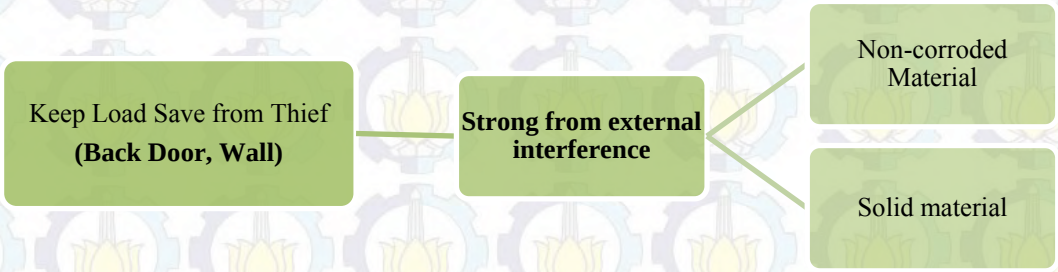


Figure 5.9 Keep Load Save from Thief Function Tree Analysis

5.3. Generate Concepts

The core part of modular function deployment is the utilization of module indication matrix to form the module candidates. The previous eight main functions are associated with 12 module drivers to look for the relationship between functions. The scoring consist of three value; 1 (one), 3 (three), and 9 (nine), while there is negative and positive value to refers the kind of relationship. Score -9 tend to show that the function should avoid modularity, while +9 refers that the function should be grouped into module based on the module drivers. If there is no relationship between functions and module drivers, the score is 0.

A carry over module driver is a module that can be used from an earlier generation product to the next generation. To protect the content from external conditions means that the related component should be long lasted, therefore it is avoid making module based on the carry over driver. Common units are standard modules that have relatively little variation due to product customization. The function to retain the load often use common unit with different product, therefore it is recommended to develop modularity for this function.

		Functions								
		Protect content from external conditions	Protect content from wheather conditions	Retain the weight of load	Air Circulation System	Loading-unloading secondary access	Loading-unloading main access	Connector with the vehicle	Keep load safe from theft	
Module Drivers	Carry Over	-9			9		9		9	**18**
	Technology Evolution		1						1	**2**
	Planned changes					-9				**-9**
	Different Specification	-9	-9		1					**-17**
	Styling	-3	1							**-2**
	Common Unit			9	3		3	9	3	**27**
	Process/organization	1	1			-1				**1**
	Separate testing	-9	-9		1		1		1	**-15**
	Supplier Availability	-9	-9	1			1	1		**-15**
	Service & Maintenance	9			1	-1	3	1	1	**14**
	Upgrading	-1					-1			**-2**
	Recycling	1	1	1		1	3	1		**8**
		-29	**-23**	**11**	**15**	**-10**	**19**	**12**	**15**	

Figure 5.10 Module Indication Matrix

After all functions and module drivers are scored, the total of column shows the priority of module drivers, but this number is not highly impacting the module development. The sum of rows shows the score of functions, and this

score become the consideration to develop modularity because functions that can be grouped into module are likely to have similar number or range. There is no fix method to develop modules, because the modularity is developed through discussion and condition of product. Therefore to develop MIM there is focus group discussion with the Production Department and Design Department of PT. X. Five modules were formed in the discussion, and shown in figure below.

		M1	M2	M3	M4			M5		
		Protect content from external conditions	Protect content from weather conditions	Loading-unloading secondary access	Keep load safe from theft	Air Circulation System	Loading-unloading main access	Retain the weight of load	Connector with the vehicle	
Module Drivers	Carry Over	-3			3	3	3			**6**
	Technology Evolution		1		1					**2**
	Planned changes			-9						**-9**
	Different Specification	-9				1				**-8**
	Styling	-3	1							**-2**
	Common Unit				3	3	3	9	9	**27**
	Process/organization	1	1	-1						**1**
	Separate testing	-9	-9		1	1	1			**-15**
	Supplier Availability		-3				1	1	1	**3**
	Service & Maintenance			-1	1	1	3		1	**5**
	Upgrading	-1					-1			**-2**
	Recycling	1	1	1				1	1	**5**
		-23	**-5**	**-10**	**9**	**9**	**10**	**11**	**12**	

Figure 5.11 Module Indication Matrix with Modules Candidates Formed

In order to classify the modularity there are four steps:

1. Sort the function score from the lowest to highest, for the score with negative value is preferred to avoid modularity. In this case, after being sorted, the final calculation shows that the highest value is 12 and the lowest value is -23. The negative value of first three functions mean that those functions are not recommended to be module.
2. Find the highest score of module drivers, and look for the functions with similar score in related drivers. The similar score shows the level of interest to be grouped based on the module driver factor. In this case, the highest module drivers are common unit and carry over. In common unit factor, air circulation system, keep the content safe and loading-unloading access function has same score which is 3, and retain load function has similar score of 9 with connector to vehicle.
3. Consider the module based on another module driver with similar score. If the functions have similar score in many module drivers, it is likely to be grouped.
4. Subjective consideration of design and production department based on actual condition.

The module development is also based on subjective consideration of design and production department. Only related components and functions that will be constructed into modules. The fifth module is combining two functions which are retaining of load weight and connect with vehicle functions. Those two functions are owned by floor and chassis components, thus it could be joint into one module.

Module Indication Matrix results new function deployment due to merger of certain functions into one module. Based on the classification there are five modules

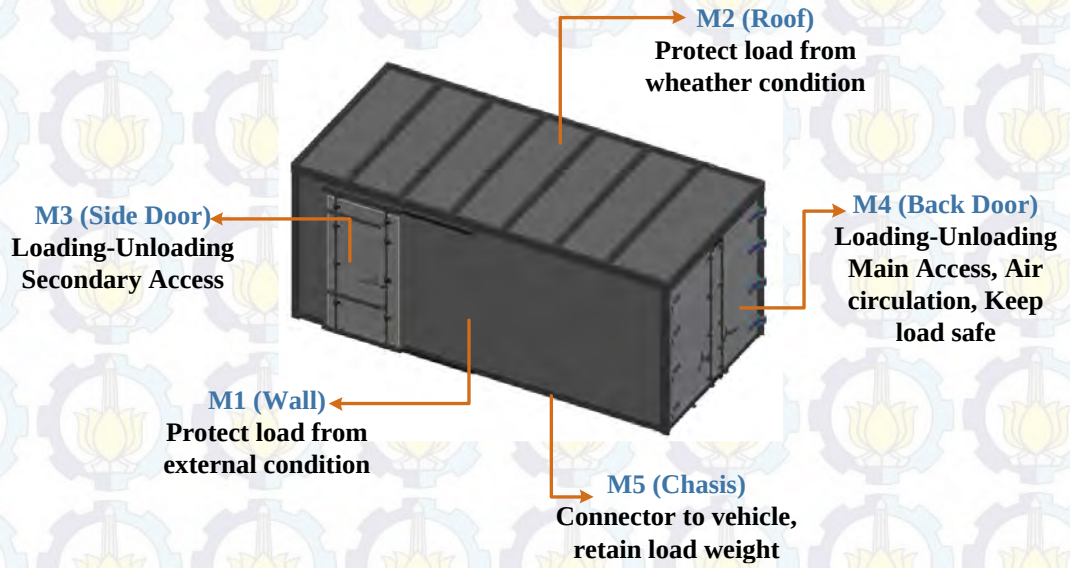


Figure 5.12 Module Main Function Deployment

5.4. Part Standardization

Standardization is important to determine which parts or components are the general or main components whether in standard product or modified product. Standard part will be connected into modular part with modified interface if necessary. Standard parts can be determined through comparison between Bill of Material from standard product and modified product, which already provided in previous chapter, and through discussion with product design department in the company. The result is standard part for chassis and roof of 4-wheels product which can be seen in tables and figures below. To ease the naming for further analysis, chassis standardized part is named S1, and roof standardized part is S2.

Table 5.2 Standard Components for Chassis (S1)

No	Component Name	Quantity	Unit
1	UNP 50x38x5	3.3	M
2	UNP 65x42x5x6	1	M

Figure 5.13 Design on S1

Table 5.3 Standard Components for Roof (S2)

No	Component Name	Quantity	Unit
1	AV Lis Atap Pot (1750)	2	Bt
2	AV Lis Atap Pot (3000)	2	Bt
3	Siku 50x50x6	4	Unit
4	AV Keliling Atap Pot (1805)	2	Bt
5	AV Keliling Atap Pot (3048)	2	Bt
6	Rusuk Besi 1735	5	Bt
7	Atap ALM 4 roda	3	Lbr

Figure 5.14 Design of S2

5.5. Module Candidate Analysis

Module Indication Matrix on previous sub-chapter results 5 alternative modules. But these modules also need to deeper analysis from interface and design factors. Therefore the modules alternatives are developed but then there is

approval from the company to sort the possible modules. Module candidates come from creativity, calculation and consideration of customer requirements and technical responses. Module candidate is developed based on the component or part. Thus there are back door, side door, wall, roof, and floor modules, and there are several alternative for each modules. Based on the component classification if Chapter 4 previously, there are two main streams of material which are aluminium based and composite based. Therefore in module development, module with aluminium as raw material will use code "A", and composite-based module will use "B".

5.5.1. M1 Alternatives

The alternative of M1 are aluminium wall and composite wall. The module will be assembles into the frame before box assembly. The detail of M1A and M1B can be seen in figures and tables below.

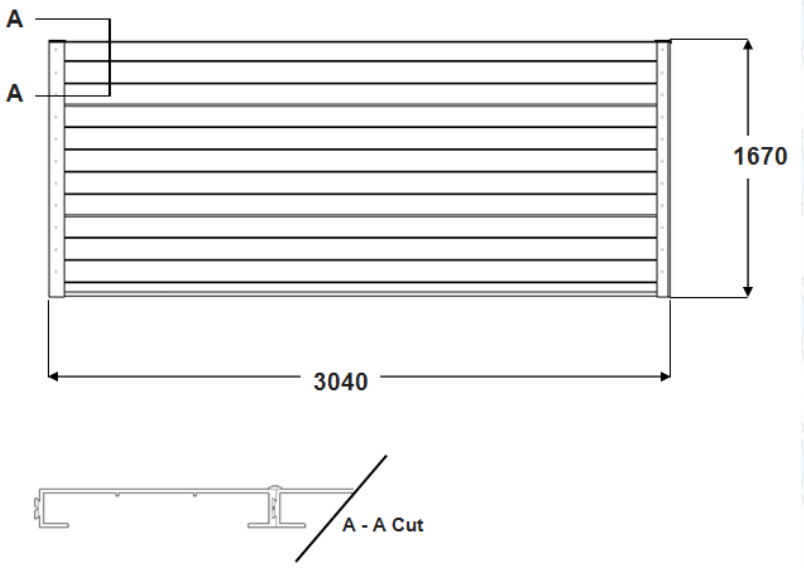


Figure 5.15 Design of M1A

Table 5.4 Component of M1A

No	Name of Component	Quantity	Unit
1	AV Dinding Strip Pot	9	Bt
2	AV Frame Pot 1750	4	Bt
3	AV Frame Pot 3000	4	Bt

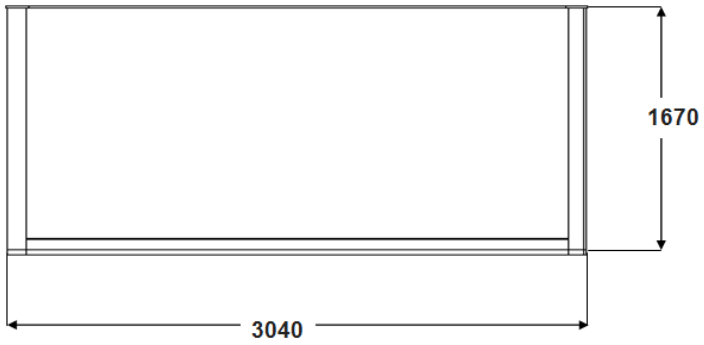


Figure 5.16 Design of M1B

Table 5.5 Component of M1B

No	Name of Component	Quantity	Unit
1	Aluminium Composite Panel	3	Lbr
2	AV Frame Pot 1750	4	Bt
3	Plat Hitam 2.3 mm	2	Lbr

5.5.2. M2 Alternatives

Roof module (M2) consists of two types which are aluminium roof and composite roof. These roof modules also will be assembled with previous roof standard component. Roof has the most standardized part, the aluminium and composite module differences only about the external cover and plate used as upper part of roof. The detail of aluminium and composite roof module can be seen in figures and tables below. The shape and size of these modules are same; the difference is only about material. Aluminium roof is named M2A and composite roof is called M2B.

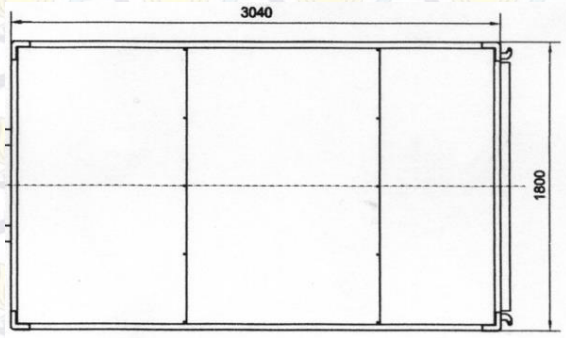


Figure 5.17 General size of roof

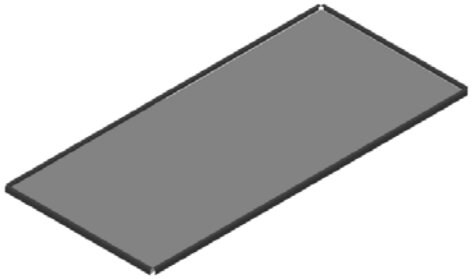


Figure 5.18 Design of M2A

Table 5.6 Component of M2A

No	Name of Component	Quantity	Unit
1	Plat hitam potong 0030x1200	0.4	Lbr
2	Plat potong penguat atap	4	Bj
3	Plat hitam potong 0030x0130	10	Bt
4	Keliling atap alm	4	Bt

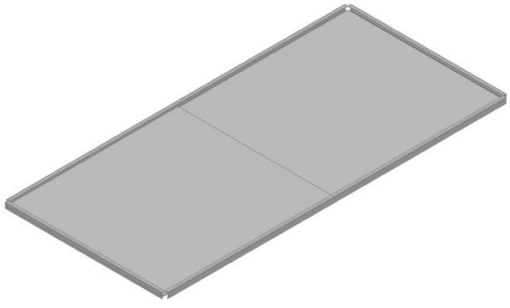


Figure 5.19 Design of M2B

Table 5.7 Component of M2B

No	Name of Component	Quantity	Unit

1	Keliling atap composite 1680	1	Bt
2	Keliling atap composite 0530	1	Bt
3	Keliling atap composite 2400	2	Bt
4	Plat potong penguat atap 100x100	4	Bj

5.5.3. M3 Alternatives

Side Door function (M3) is custom function which ordered by customers. The module is needed to ease production process if there is demand from the customers. For side door, there is only aluminium-based side door, M3A, because there is no side door for composite box. Or it is very unlikely.

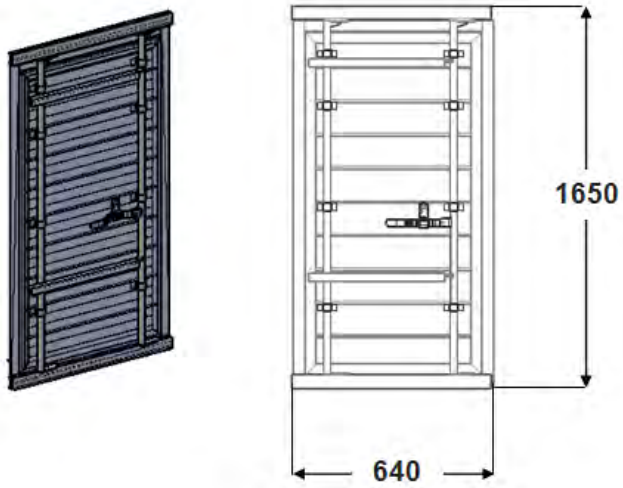


Figure 5.20 Design of M3A

Table 5.8 Component of M3A

No	Name of Component	Quantity	Unit
1	AV Hollo Pot	10	Bt
2	Sok Pintu Kecil	8	Bj
3	Sok Pintu Kecil 0030	2	Bj
4	Handel + Klathok	1	Set
5	Siku Penguat Kusen	4	Bj

5.5.4. M4 Alternatives

Back Door (M4) also consists of two types which are aluminium door and composite door. Due to the location of door in which the height of product can be raised, the aluminium module is considering the adjustable height. Composite module consists of more complete component since it is

not possible to add the height, because the capability of composite itself. The detail of aluminium and composite back door module can be seen in figures and tables below. Aluminium back door is named M4A, and composite door is named M4B.

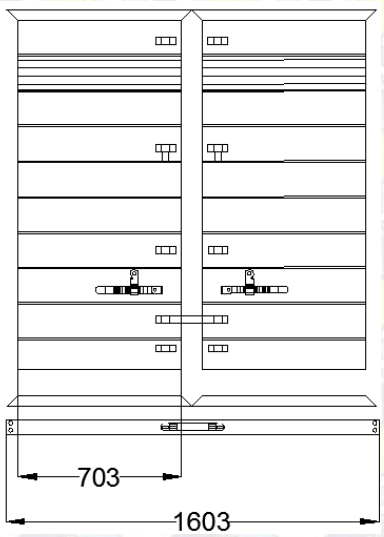


Figure 5.21 Design of M4A

Table 5.9 Component of M4A

No	Name of Component	Quantity	Unit
1	AV Hollo Pot	16 - 18	Bt
2	AV Angin-angin Pot	2	Bt
3	Sok Pintu Besar 0020	12	Bj
4	Sok Pintu Besar 0030	2	Bj
5	Siku penguat kusen	4	Bj
6	Ring Cincin	4	Bt

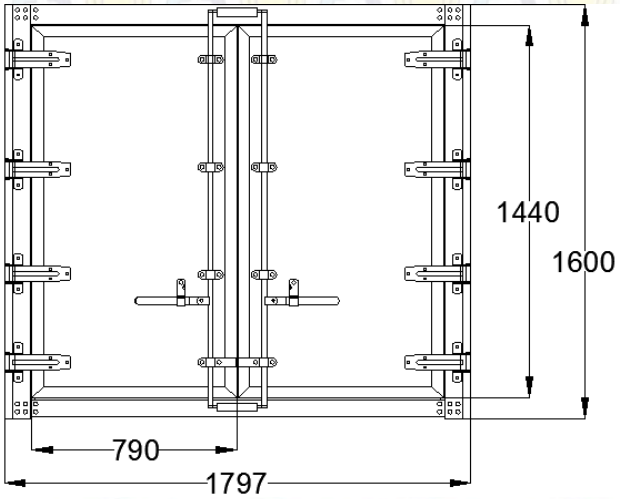


Figure 5.22 Design of M4B

Table 5.10 Component of M4B

No	Name of Component	Quantity	Unit
1	AV Lis Pintu Baru	1	Bt
2	AV Frame Pot	4	Bt
3	Sok Pintu Besar	3	Bt
4	Omega pintu composite 1330	6	Bt
5	Lis Aluminium Pancing	9	Ljr
6	Ring Cincin	4	Bt
7	Melamin putih	1	Lbr
8	Pipa pintu belakang 1490	2	Bt

5.5.5. M5 Alternatives

M5 is floor module, in which basically there are two types of floor which are aluminium floor that consists of series of aluminium plate and composite floor that consists of composite board and frame. These floor modules will be assembled with chassis standard component from previous chapter. Aluminium floor will directly be connected with rivet and ring ver to chassis, while composite floor will connect the frame and plate to chassis. The detail of aluminium and composite floor module can be seen in figures and tables below. Aluminium floor module is called M5A and composite module is called M5B.

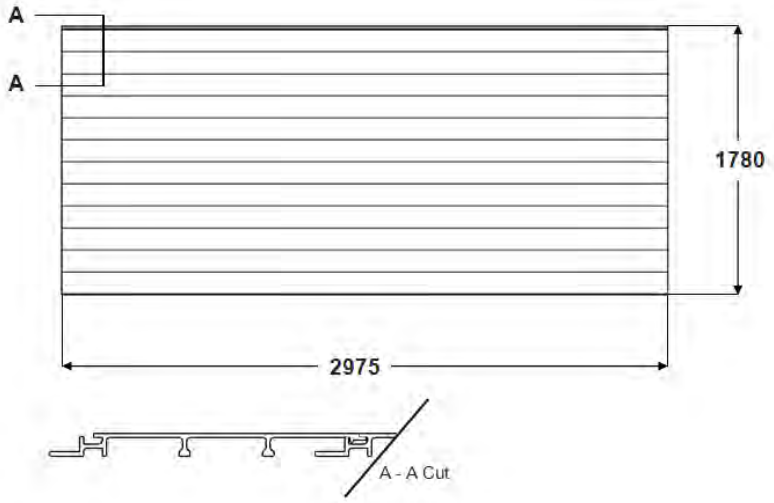


Figure 5.23 Design of M5A

Table 5.11 Component of M5A

No	Name of Component	Quantity	Unit
1	AV Lantai Pot	12	Bt
2	Siku 40x40x6	4	Bj

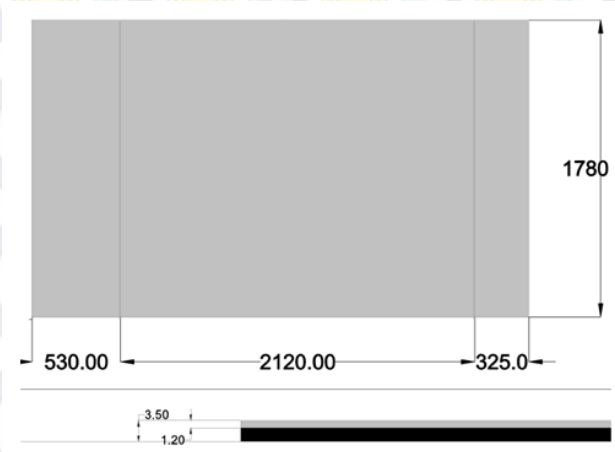


Figure 5.24 Design of M5B

Table 5.12 Component of M5B

No	Name of Component	Quantity	Unit
1	Cover Lantai Composite P.2400	1	Bt
2	Plat Hitam 2.3 mm x 4 x 8	2	Lbr
3	Cover Lantai Depan Composite	1	Bt
4	Cover Lantai Composite 530 x 1.2	1	Bt

5.6. Evaluate Modules

The previous candidates of modules are discussed with Production Department and Design Department to briefly determine the feasibility. The discussion results approved module candidates, while the other is rejected because of certain reasons. This evaluation is considering practical evaluation (condition that only known by the company) since previously modules only analyzed and classified based on function and analytical evaluation. The discussion is attached in Appendix F, and summarized in table below.

Table 5.13 Module Candidates Decision

Module	Decision	Note (Practical Evaluation)
S1	√	Accepted
S2	√	Accepted
M1A	X	• The components required large area to be stored, which is not comparable with the result. The components easily damaged if not assembled just before box Assembly • Cost of components are very expensive and also used for other products, thus modularity will absorb high value of resources
M1B	X	• The components required large area to be stored, which is not comparable with the result. • The components easily damaged if not assembled just before box assembly
M2A	X	• The component is only board, required large area to be stored which is not comparable with the result • Cost of components are very expensive and also used for other products, thus modularity will absorb high value of resources
M2B	X	• The component is only board, required large area to be stored which is not comparable with the result • The components easily damaged if not assembled just before box assembly
M3A	X	• High demand of varieties size and design, and it is preferable to be custom production.
M4A	√	Accepted
M4B	√	Accepted
M5A	√	Accepted
M5B	√	Accepted

In several modules the constraint is the component is very expensive and also used for 6-wheels and 10-wheels. Actually the possibility to develop modules among 4, 6, and 10-wheels products is already considered, but there are difficulties based on the design of the product. As can be seen in figure 5.25 below, that the size of 4, 6, and 10-wheels product is vary and not multiple.

Therefore the modularity and standardization is very difficult to be implemented among those size. Beside there is another consideration in developing modularity and standardization in this type of product such as the tensile strength or mechanic characteristic of product if it is formed into modules.

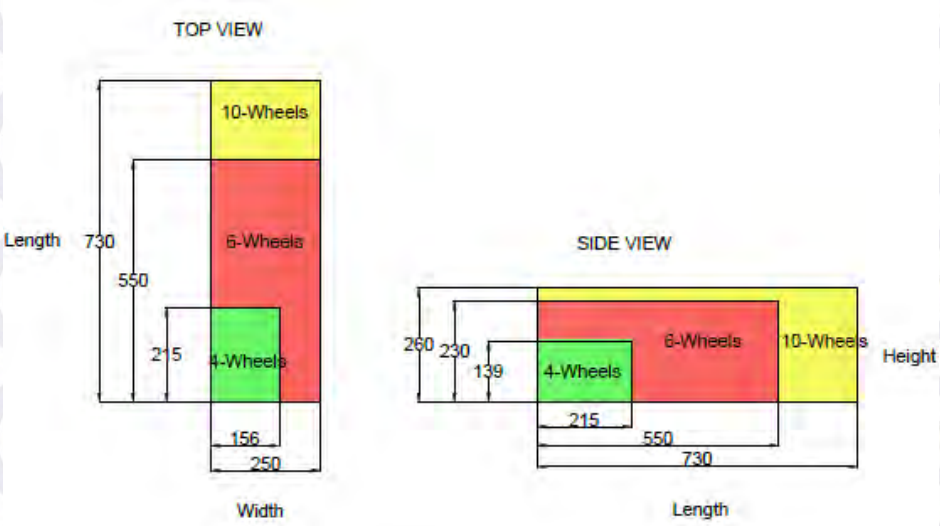


Figure 5.25 4, 6, and 10-wheels Size Comparison

CHAPTER 6
DEVELOPED MODULES TESTING AND ANALYSIS

Chapter 6 discusses about the gap between current condition and proposed improvement from certain aspects. Thus this chapter will consist of Process Analysis, Production Time Analysis, Lead Time Analysis (Case Study), Inventory Analysis, and Cost Analysis.

6.1. Process Analysis

Process analysis is done by recreate the Operation Process Chart of the proposed modules and standardized parts, to represents the general production flow difference. Actually there is no changing in detail process because all the processes is done similar with the current condition but only classified or re-arranged into modules and standardized part. The FPC of chassis standardized part can be seen in figure below.

SUMMARY			DETAIL						
	No	Time (min)	Job : CHASIS STANDARDIZED (Rakit Chasis Standard)						
Operation	13	50.59							
Transportation	1	0.45							
Delay	0	0.00	Type: ■ Material □ Worker □ Machine					Chart No : 1 of	
Inspection	1	0.54	Method: ■ Present □ Proposed					Date : January 2016	
Inventory	1	0.00	Chart Start : Components					Created by : Viona Claresta	
Total	16	51.58	Chart End : Floor Sub-Assembly					Checked by : PT Adicitra Bhirawa	

Activity	Operation	Transportation	Delay	Inspection	Inventory	Operation Duration (sec)	Moving Duration (sec)	Delay Duration (sec)	Material	Equipment
Preparation	○	⇨	D	□	▽	228.09				
Measurement	○	⇨	D	□	▽	236.29				
Cutting: mounting support	○	⇨	D	□	▽	233.28			Siku 40x40x6	
Welding: 4 points	○	⇨	D	□	▽	120.61				Welding rod
Welding: 12 points right	○	⇨	D	□	▽	185.79				Welding rod
Welding: 12 points left	○	⇨	D	□	▽	184.55				Welding rod
Welding: 24 points right	○	⇨	D	□	▽	486.36				Welding rod
Welding: 24 points left	○	⇨	D	□	▽	426.87				Welding rod
Installing: *rusukkanan*	○	⇨	D	□	▽	186.66			UNP 50x38x5x6	
Installing: *rusuk fondasi bawah*	○	⇨	D	□	▽	285.68			UNP 65x42x5x6	
Attaching: lower framework (2 points)	○	⇨	D	□	▽	201.28				
Painting (covering welding points)	○	⇨	D	□	▽	187.28				
Transportation	○	⇨	D	□	▽		26.9			Hoist
Centering	○	⇨	D	□	▽	40.87				
Inspection	○	⇨	D	□	▽	32.51				
Inventory	○	⇨	D	□	▽					

Figure 6.1 FPC of S1

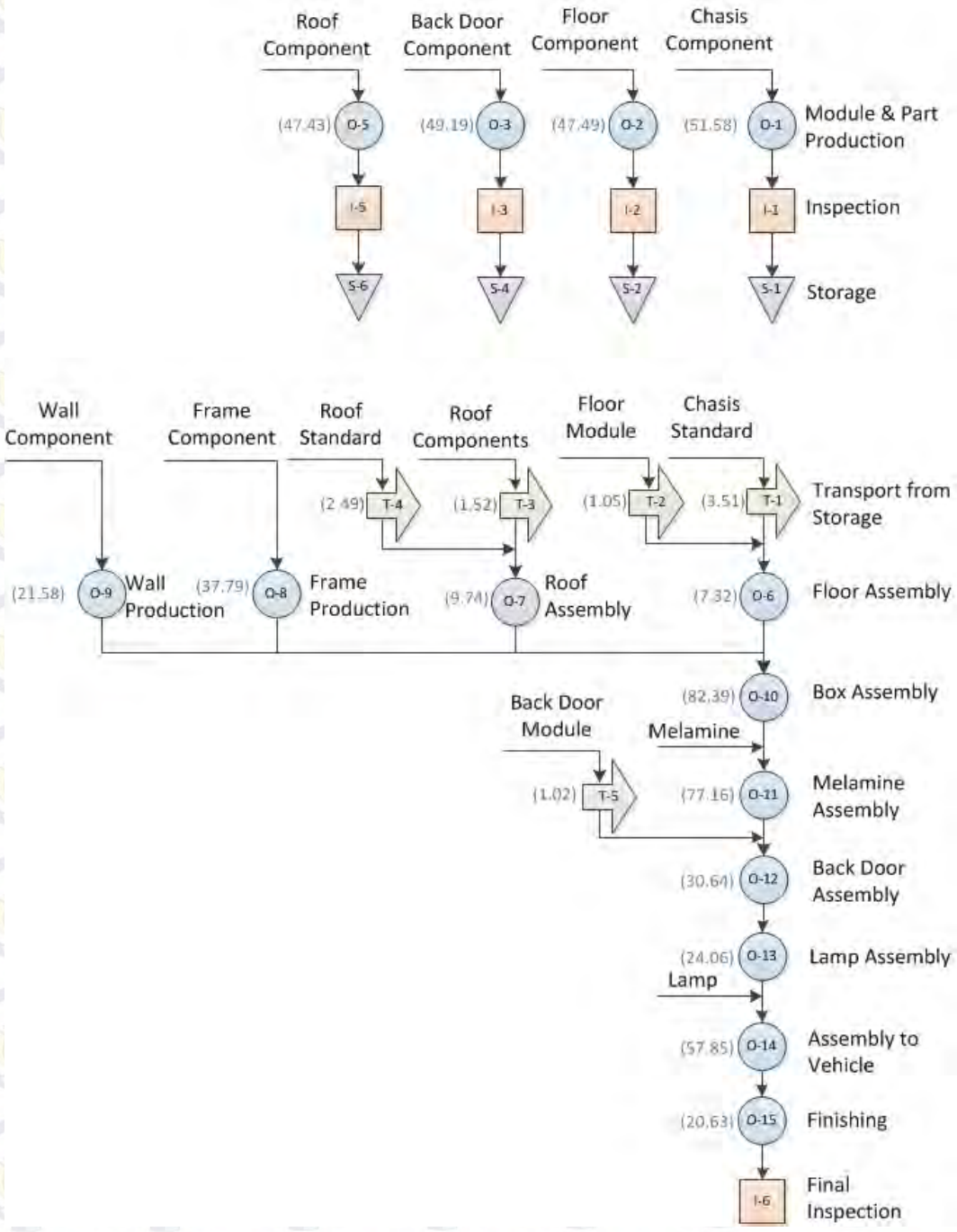


Figure 6.2 Improvement System OPC

In current condition the production process starts from components (raw material) of each sub-assembly, however in proposed system half of the sub-assemblies have been produced into modules and the production process starts from standardized parts and modules. From OPC figure above, it is noted that since some of the parts already produced separately, the activities are mostly

assembling. Despite the OPC seems like more complex because the occurrence of transportation processes, but the production time become shorter.

6.2. Production Analysis

Production analysis consists of production time analysis, production capacity analysis and unit per man-hour analysis. All those analysis are related to production system to know the gap between current system and proposed system.

6.2.1. Production Time Analysis

Production time analysis is done on each approved module and standardized part to know the reduction in production time. The reduction is calculated by deleting the related processes to construct modules from main production process, and calculate the percentage of reduction.

For example the reduction time of S1 calculation. The production to make chassis standardized part is 51.58 minutes, and then it means that the production lead time will be decreased as well. Therefore the production lead time will be only 332.26 minutes, which is reduced by 13.44%. The calculation for each module and standardized part is provided in table below.

Table 6.1 Reduction of Production Time per Module and Standardized Part

No	Module/Standardized Part	Production Time of Module/Part	Percentage Lead Time Reduction
1	S1	51.58	13.44%
2	S2	47.43	12.36%
3	M4A	49.19	12.81%
4	M4B	42.64	11.11%
5	M5A	32.95	8.58%
6	M5B	37.29	9.71%

Beside the reduction per module and standardized part there is also production time reduction analysis for combination of standardized part and module. In order to develop the combination, the possible conditions of module combination are made as written in following table.

Table 6.2 Possible Module Combinations

No	S1	6.2.2. 2	6.2.3. M4 and M5
1	Using standard part	Using standard part	Using M4A only
2	Not using standard part	Not using standard part	Using M4B only
3			Using M5A only
4			Using M5B only
5			Using M4A and M5A Module
6			Using M4B and M5B Module
7			Not using modules

In developing module combinations, roof and floor modules combined under consideration because roof and floor is based on type of product, thus it is not possible to combine aluminium roof with composite floor or vice versa. Aluminium roof should be combined with aluminium floor, and so for composite. From those possibilities, there are 20 alternatives and the calculation is provided in table below.

Table 6.3 Module Combinations Lead Time Reduction Analysis

No.	Standardized		Modules	Total Time Reduction (min)	Percentage of Time Reduction
1	S1	S2	M4A + M5A	181.15	47.19%
2	S1	S2	M4B + M5B	178.94	46.62%
3	S1	S2	M4A	148.2	38.61%
4	S1	S2	M4B	141.65	36.90%
5	S1	S2	M5B	136.3	35.51%
6	S1		M4A + M5A	133.72	34.84%
7	S1	S2	M5A	131.96	34.38%
8	S1		M4B + M5B	131.51	34.26%
9		S2	M4A + M5A	129.57	33.76%
10		S2	M4B + M5B	127.36	33.18%
11	S1		M4A	100.77	26.25%
12	S1	S2		99.01	25.79%
13		S2	M4A	96.62	25.17%

Table 6.3 Module Combinations Lead Time Reduction Analysis (con't)

No.	Standardized		Modules	Total Time Reduction (min)	Percentage of Time Reduction
14	S1		M4B	94.22	24.55%
15		S2	M4B	90.07	23.47%
16	S1		M5B	88.87	23.15%
17		S2	M5B	84.72	22.07%
18	S1		M5A	84.53	22.02%
19			M4B + M5B	82.14	21.40%
20		S2	M5A	80.38	20.94%
21			M4A + M5A	79.93	20.82%

From the alternatives calculation above it is known that the highest time reduction is by combining S1, S2, M4A and M5A, which reduce 47.19% of total lead time. Meanwhile combination of M4A and M5A only reduce 20.82% as the lowest lead time reduction.

6.2.4. Production Capacity Analysis

Production capacity is the number of product produced in certain time period. The value of production capacity shows the capability of company to fulfil demand, or in other way production capacity is the maximum demand that can be fulfiled by company in normal production time. Production capacity is calculated by dividing total production duration with . In current condition one product will be finished in 377.4 minutes while one working day consists of 480 minutes. In proposed system, the highest time reduction only requires 196.25 minutes for one product.

$$Production\ capacity = \frac{Available\ Working\ Time}{Lead\ time}$$

$$Production\ capacity\ (current) = \frac{480\ min}{377.4\ min} = 1.27\ unit/day$$

$$Production\ capacity\ (combination\ 1) = \frac{480\ min}{196.25\ min} = 2.45\ unit/day$$

The complete calculation for all combination and current condition is provided in Appendix G.

6.3. Inventory Analysis

General concept of Modularity and Product-Service System requires production system with high variation product and short lead time. It leads into hybrid production type between Make-to-Order and Make-to-Stock system, or in other hand Mass Production and Custom Production. Previous analysis and calculation clearly shows that PT. X requires stock or inventories in determined parts and modules. Currently PT.X does not have structure inventory system, the raw materials are ordered based on the demand from customer and there is no inventory quantity checking.

In order to determine stock level and order period there are many methods that can be used. The method used in this calculation is Periodic Review, by considering condition of PT. X such as:

- Uncertain demand
- Characteristic of stock which is easily countable
- Lead time of inventory delivery (in this case is the lead time to produce modules) is constant and known
- The method is easy to be implemented in the company

The inventory analysis is only done on the aluminium-based products. Based on Periodic Review method, there are several variables required such as; demand standard deviation and mean, checking period, service level, and lead time of inventory delivery. Average demand and standard deviation is received from analysis of historical demand data. Stock checking is done every day, and the lead time is also one day. Every day checking is applied by company to reduce the number of inventory, because longer checking period will result larger inventories. The calculation of safety stock is provided in table below, and there is calculation sample of M4A:

$$Average\ Demand = D = 3\ units/day$$

$Standard\ Deviation = \ \sigma = 2\ unit$

$Checking\ Period = T = 1\ day$

$Lead\ Time = \ LT = 1\ day$

$Service\ Level = 95\%$

$Z = \ 1.64$

$Safety\ Stock = \ Z \times \sigma \times \sqrt{(T + LT)}$

$Safety\ Stock = \ 1.64 \times 2 \times \sqrt{(1 + 1)}$

$Safety\ Stock = 4.63 \approx 5\ units$

$Target\ Stock\ Level = D \times (T + LT) + safety\ stock$

$Target\ Stock\ Level = 3 \times (1 + 1) + 5$

$Target\ Stock\ Level = 11\ units$

Table 6.4 Modules Safety Stock Calculation

Module	Average Demand	Std Dev	z-value	T	LT	SS	Target SS
S1	3	2	1.64	1	1	5	11
S2	3	2	1.64	1	1	5	11
M4A	3	2	1.64	1	1	5	11
M4B	1	1	1.64	1	1	3	5
M5A	3	2	1.64	1	1	5	11
M5B	1	1	1.64	1	1	3	5

The calculation above shows that although the average demand is only 3 units per day, the safety stock and target stock level is quite high. This condition occurs due to the fluctuate demand which results high standard deviation. Standard deviation refers to the variance of demand, thus the demand is very unstable and possible to increase sharply, so high number of stock is required to prevent stock out. Target stock level shows the minimum number of inventory that required on each checking period. It means at the end of every day, there should be at least 11 units of each standardized parts and modules of aluminium. Since there are 2 standardized parts and 2 modules, the total inventory would be 44 units. The sample calculation of replenishment can be seen in table below.

Table 6.5 Replenishment of M4A

Day	Demand	Inventory	Reorder	Order size
1	0	11	no	0
2	2	9	yes	2
3	3	8	yes	3
4	1	10	yes	1
5	4	7	yes	4
6	0	11	no	0
7	2	9	yes	2
8	0	11	no	0
9	4	7	yes	4
10	3	8	yes	3
11	4	7	yes	4
12	3	8	yes	3
13	2	9	yes	2
14	3	8	yes	3
15	1	10	yes	1
16	4	7	yes	4
17	2	9	yes	2
18	0	11	no	0
19	4	7	yes	4
20	1	10	yes	1

Inventory column shows the on hand inventory which is the result of previous inventory and used inventory and added with order size on previous period. Reorder decision in based on the on-hand inventory, if the value is less than target safety stock which is 11, there should be reorder as much as written in the order size. The order size is equal to target safety stock minus inventory on hand. The principle of this calculation is to keep the inventory on-hand as much as target safety stock.

6.4. Cost Analysis

As there is changing in production system and additional inventory, there will be additional cost to the company, but due to lead time reduction the labour cost is also decreasing. Thus there is cost analysis to calculate the inventory cost and labour cost.

6.4.1. Inventory Cost

To calculate the inventory cost, the price of each standard product and module should be known, and then the holding cost is calculated by assuming 10% of the product value. The holding cost calculation for standardized parts and modules are provided in Table 6.5 – 6.11 below. In the calculation there are Qty 1 and Qty 2 of component, Qty 1 refers to the quantity of components counted in unit, while Qty 2 refers to the unit of buying from the supplier. For example AV Keliling Atap Pot is counted as 2 units or 2 pieces of aluminium sheet, but the aluminium sheet is bought in kilogram from the supplier, thus 2 sheets equal to 5.01 kilograms. The price list is based on the Qty 2, therefore the total price is equal to Qty 2 multiplied by Price.

Table 6.6 Holding Cost S1

S1						
No	**Component**	**Qty 1**	**Qty 2**	**Price**	**Total Price**	
1	UNP 65 X 42 X 5 X 6 M	1	1	Rp 181,442.91	Rp	181,442.91
2	UNP 50 X 38 X 5 X 6 M	3.3	3.3	Rp 123,660.96	Rp	408,081.17
3	LABOUR COST			Rp 38,548,89	Rp	38,548,89
TOTAL					Rp	628,072.97
HOLDING COST (10%)					Rp	62,807.30
TOTAL HOLDING COST (11 UNITS)					**Rp**	**690,880.26**

Table 6.7 Holding Cost S2

S2						
No	**Component**	**Qty 1**	**Qty 2**	**Price**	**Total Price**	
1	AV KELILING ATAP POT	2	5.01	Rp 46,000.00	Rp	230,460.00
2	AV KELILING ATAP POT	2	8.46	Rp 46,000.00	Rp	389,160.00
3	AV LIS ATAP POT	2	1.81	Rp 46,000.00	Rp	83,260.00
4	AV LIS ATAP POT	2	3.1	Rp 46,000.00	Rp	142,600.00
5	ATAP ALM 4 RODA	3	3	Rp 196,740.00	Rp	590,220.00
6	RUSUK BESI 1735	5	5	Rp 38,520.00	Rp	192,600.00
7	SIKU 50 X 50 X 6 M	4	0.03	Rp 222,635.43	Rp	6,679.06
8	LABOUR COST			Rp 23,242.64	Rp	23,242.64
TOTAL					Rp	1,658,221.70
HOLDING COST (10%)					Rp	165,822.17
TOTAL HOLDING COST (11 UNITS)					**Rp**	**1,824,043.87**

Table 6.8 Holding Cost M4A

M4A					
No	**Component**	**Qty 1**	**Qty 2**	**Price**	**Total Price**
1	AV HOLLO POT	16	17.97	Rp 46,000.00	Rp 826,620.00
2	AV ANGIN-ANGIN POT	2	2.75	Rp 46,000.00	Rp 126,500.00
3	SOK PINTU BESAR P0020	12	12	Rp 2,255.00	Rp 27,060.00
4	SOK PINTU BESAR P0030	2	2	Rp 3,260.00	Rp 6,520.00
5	RING CINCIN	4	4	Rp 24.66	Rp 98.64
6	SIKU PENGUAT KUSEN	4	4	Rp 6,600.00	Rp 26,400.00
7	LABOUR COST			Rp 9,385.28	Rp 9,385.28
TOTAL					**Rp 1,022,583.92**
HOLDING COST (10%)					Rp 102,258.39
TOTAL HOLDING COST (11 UNITS)					**Rp 1,124,842.31**

Table 6.9 Holding Cost M4B

M4B					
No	**Component**	**Qty 1**	**Qty 2**	**Price**	**Total Price**
1	AV LIS PINTU BARU	1	1	Rp 5,313.40	Rp 5,313.40
2	AV FRAME POT	4	2.22	Rp 46,000.00	Rp 102,120.00
3	SOK PINTU BESAR	3	3	Rp 3,260.00	Rp 9,780.00
4	OMEGA PINTU COMPOSITE	6	6	Rp 30,575.00	Rp 183,450.00
5	LIS ALUMINIUM PANCING	9	9	Rp 4,905.35	Rp 44,148.15
6	RING CINCIN	4	4	Rp 24.66	Rp 98.64
7	MELAMIN PUTIH	1	1	Rp 94,995.56	Rp 94,995.56
8	PIPA PINTU BELAKANG	2	2	Rp 34,150.00	Rp 68,300.00
9	LABOUR COST			Rp 9,385.28	Rp 9,385.28
TOTAL					**Rp 517,591.03**
HOLDING COST (10%)					Rp 51,759.10
TOTAL HOLDING COST (5 UNITS)					**Rp 258,795.51**

Table 6.10 Holding Cost M5A

M5A					
No	**Component**	**Qty 1**	**Qty 2**	**Price**	**Total Price**
1	LANTAI POT	12	41.91	Rp 45,720.00	Rp 1,916,125.20
2	AV SIKU ALAS POT	2	3.63	Rp 44,000.00	Rp 159,720.00
3	LABOUR COST			Rp 23,857.36	Rp 23,857.36
TOTAL					Rp 2,099,702.56
HOLDING COST (10%)					Rp 209,970.26
TOTAL HOLDING COST (11 UNITS)					**Rp 2,309,672.82**

Table 6.11 Holding Cost M5B

M5B					
No	Component	Qty 1	Qty 2	Price	Total Price
1	COVER LANTAI COMPOSITE	1	1	Rp 87,583.00	Rp 87,583.00
2	PLAT HITAM 2.3 MM X 4 X 8	2	2	Rp 6,000.00	Rp 12,000.00
3	COVER LANTAI DEPAN	1	1	Rp 92,889.62	Rp 92,889.62
4	COVER LANTAI COMPOSITE 5	1	1	Rp 94,995.56	Rp 94,995.56
5	LABOUR COST			Rp 23,857.36	Rp 23,857.36
TOTAL					**Rp 311,325.54**
HOLDING COST (10%)					Rp 31,132.55
TOTAL HOLDING COST (5 UNITS)					**Rp 155,662.77**

Table 6.12 Total Holding Cost

NO	MODULES	HOLDING COST
1	S1	Rp 648,476.49
2	S2	Rp 1,798,476.97
3	M4A	Rp 1,114,518.50
4	M4B	Rp 200,386.18
5	M5A	Rp 2,283,429.72
6	M5B	Rp 143,734.09
TOTAL		**Rp 6,189,021.94**

6.4.2. Labour Cost

Since the lead time of one product is reduced, the labour cost per unit product is also reducing. The value of labour cost is equal to total payment for labours per day divided by total unit produced. There are 22 labours to finish one product with payment of Rp 200,000.00 per day. Current system takes 377.4 minutes to produce 1 product, thus in one working day (8 hours) there are 1.27 products. The labour cost calculation is:

$$Labor\ Cost = \frac{Number\ of\ labor \times salary}{Unit\ produced}$$

$$Labor\ Cost = \frac{22 \times Rp\ 200{,}000.00}{1.27} = Rp\ 3{,}459{,}500.00/unit$$

The labour cost will decrease when the unit produced increase, and the unit produced will increase when lead time is decrease. From previous production time analysis, the highest lead time reduction is 47% which makes one product will be done in 196.25 minutes, and in one day there will be 2.45 products. The labour cost is:

$$Labor\ Cost = \frac{22 \times Rp\ 200{,}000.00}{2.45} = Rp\ 1{,}798{,}958.33/unit$$

6.5. Layout Analysis

The layout of production floor will be slightly changed due to additional inventory of standardized part and modules. The inventory will be placed in incidental workspace at Hall C. Hall C previously used only for wood truck and additional workspace during high demand. Thus the usage of this space for storage will not very influential. Also, Hall C is close with assembly area, in which the module only requires assembly with other parts. This layout analysis is only brief analysis as space requirement for storing inventory, not detail analysis about work flow. In space requirements calculation, allowance should be 20%-40% of total area (Sule, 1998), thus the allowance used is 20% because the size of work piece is 2-4 m (Ariwibowo, 2008).

Table 6.13 Space Requirements Calculation

No	Module	Length (m)	Width (m)	Area (m^2)	Allowance (20%)	Area + Allowance (m^2)
1	S1	3.3	1.74	5.74	1.148	6.888
2	S2	3.04	1.8	5.47	1.094	6.564
3	M4A	1.6	1.8	2.88	0.576	3.456
4	M4B	1.6	1.8	2.88	0.576	3.456
5	M5A	2.97	1.78	5.29	1.058	6.348
6	M5B	2.97	1.78	5.29	1.058	6.348
TOTAL						**33.06**

Current storage system in company is using shelve which means lately the modules will stored vertically. This system greatly saves space, the modules and parts will only need shelves with appropriate length and width. The number of modules and parts is also not very influential since the thickness of material will not exceed 30 cm, thus even 11 modules does not require high shelves. Even more, the company is planning to implement carousel storage system in the future, and this system will support modules storage. Figure below is an illustration of module storage in Hall C.

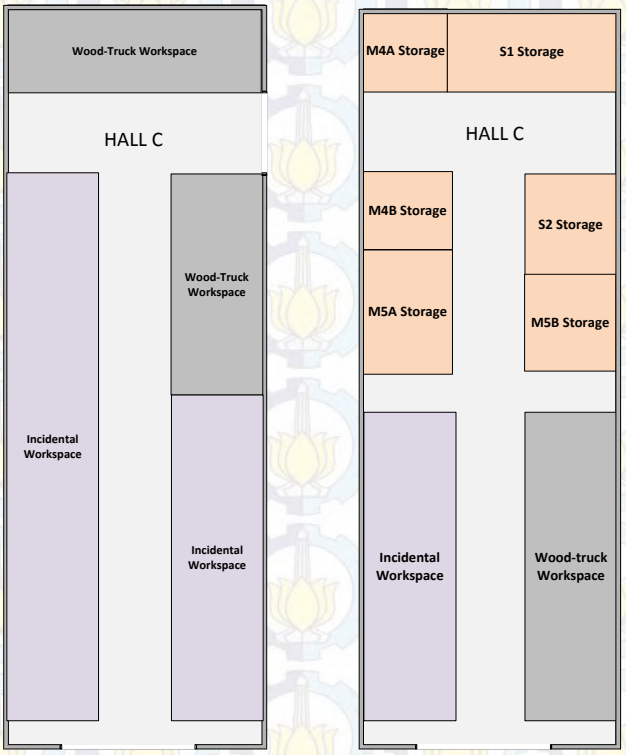


Figure 6.3 Hall C Layout (a. Current Condition; b. Proposed System)

6.6. PSS Analysis

For now modularity is implemented to overcome lead time and flexibility problems in the company, but in the future modularity will support Product-Service System. In PSS there will be additional service provided as a bundle with the product, the service such as maintenance, leasing, renting, and others. Therefore the company need to consider the possibility of PSS mechanism through modularity.

The main concept of modularity implementation to PSS is the product-life cycle concept in which the company has responsibility of the product during the lifetime. In leasing or renting when the product is damaged or broken, the customer will return the product to be repaired in the company. Therefore the company required quick replacement and repairing system so the customer does

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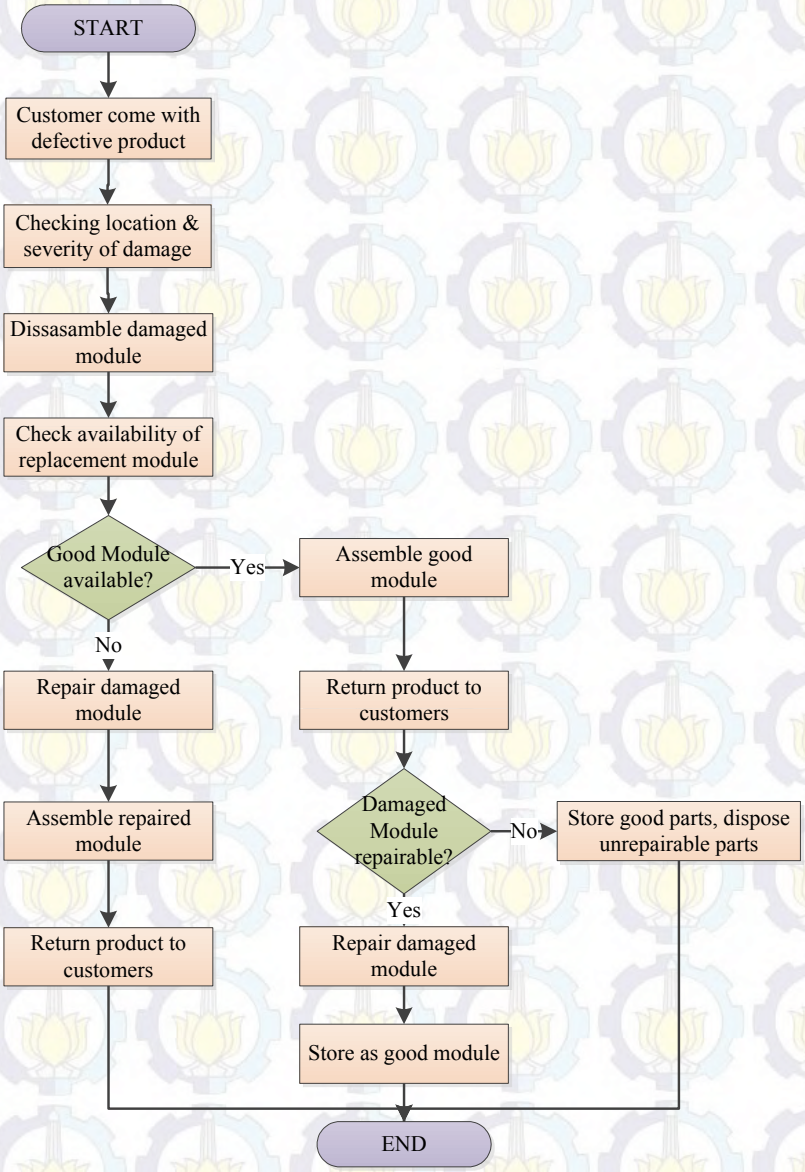

Figure 6.4 Maintenance Flowchart with Modularity System

It can be seen in Figure 6.4 that the damaged module will be disassembled and replaced with good module from storage, and if there is no stock in storage the module will be repaired. This replacement method is faster

than current maintenance system since the module will directly replaced with new one without explode or disassemble all components. The previous damaged module will be repaired and stored to be used to other damaged module later.

CHAPTER 7
CONCLUSIONS AND SUGGESTIONS

This chapter consists of conclusions of this research based on previous calculation and analysis, and also suggestions for the future research to enhance this topic.

7.1. Conclusions

There are several conclusions that can be taken from calculation and analysis in this research of modularity such as:

1. There are two alternatives of standard parts and 6 alternatives of modules that proposed but only 4 modules approved. The standard parts are called S1 and S2, while the modules are M4A and M5A for aluminium-based modules; M4B and M5B for composite-based module.
2. Proposed system can reduce lead time up to 47.19% which previously takes 6.29 hours, increase production capacity become 2.45, and reduce labour cost into Rp 1,798,958.33/unit produced.
3. The changes in production system result additional inventory to the company. There should be at least 11 units for each of S1, S2, M4A and M5A; and 5 units for each of M4B and M5B by each day. The inventory also adds cost for company as much as Rp 6,189,021.94. Hall C will be used as storage for standardized parts and modules.

7.2. Suggestions

This research is yet perfect, there are many improvements that can be done in future research to support and improve this research. The suggestions that can be given for further research are:

1. Review the standardized and modules design through mechanical testing and calculation to further examine the feasibility of design.

2. Consider the production schedule for other products in the company as consideration for standardized part and module production.
3. Consider modularity development among 4, 6, and 10-wheels product.
4. Review inventory calculation for larger time horizon and more detail constraints
5. Calculate the cost for modularity implementation in larger scope, not only holding cost and labour cost
6. Consider stochastic demand for further calculation and analysis
7. Do detail layout analysis by considering work flow

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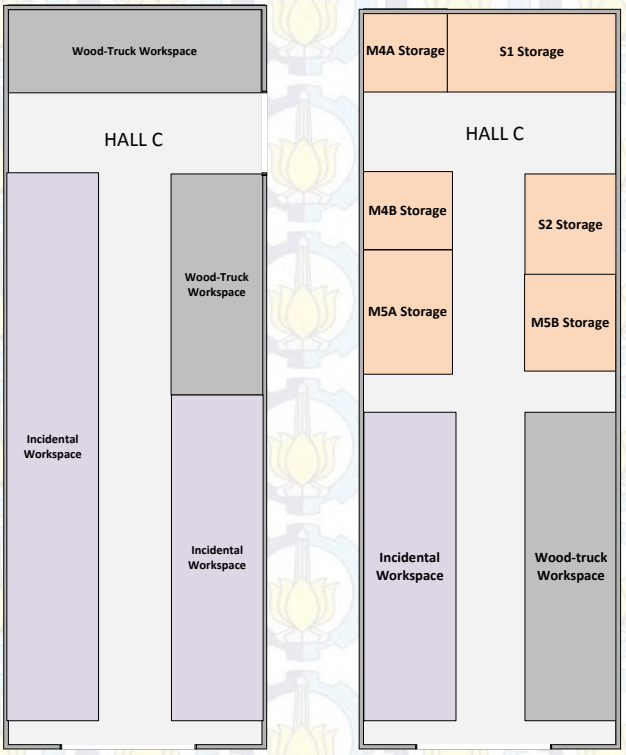
Table 6.13 Space Requirements Calculation

No	Module	Length (m)	Width (m)	Area (m^2)	Allowance (20%)	Area + Allowance (m^2)
1	S1	3.3	1.74	5.74	1.148	6.888
2	S2	3.04	1.8	5.47	1.094	6.564
3	M4A	1.6	1.8	2.88	0.576	3.456
4	M4B	1.6	1.8	2.88	0.576	3.456
5	M5A	2.97	1.78	5.29	1.058	6.348
6	M5B	2.97	1.78	5.29	1.058	6.348
TOTAL						**33.06**

Current storage system in company is using shelve which means lately the modules will stored vertically. This system greatly saves space, the modules and parts will only need shelves with appropriate length and width. The number of modules and parts is also not very influential since the thickness of material will not exceed 30 cm, thus even 11 modules does not require high shelves. Even more, the company is planning to implement carousel storage system in the future, and this system will support modules storage. Figure below is an illustration of module storage in Hall C.



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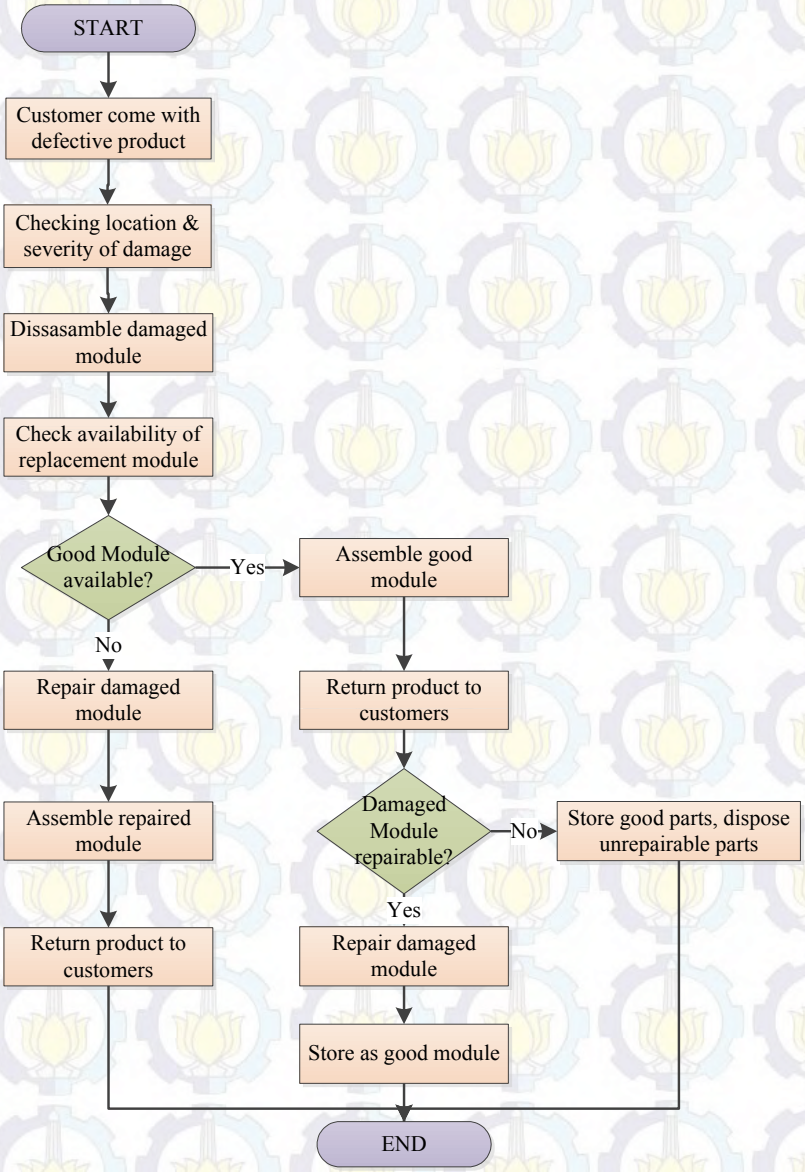

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It can be seen in Figure 6.4 that the damaged module will be disassembled and replaced with good module from storage, and if there is no stock in storage the module will be repaired. This replacement method is faster

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This chapter consists of conclusions of this research based on previous calculation and analysis, and also suggestions for the future research to enhance this topic.

7.1. Conclusions

There are several conclusions that can be taken from calculation and analysis in this research of modularity such as:

1. There are two alternatives of standard parts and 6 alternatives of modules that proposed but only 4 modules approved. The standard parts are called S1 and S2, while the modules are M4A and M5A for aluminium-based modules; M4B and M5B for composite-based module.
2. Proposed system can reduce lead time up to 47.19% which previously takes 6.29 hours, increase production capacity become 2.45, and reduce labour cost into Rp 1,798,958.33/unit produced.
3. The changes in production system result additional inventory to the company. There should be at least 11 units for each of S1, S2, M4A and M5A; and 5 units for each of M4B and M5B by each day. The inventory also adds cost for company as much as Rp 6,189,021.94. Hall C will be used as storage for standardized parts and modules.

7.2. Suggestions

This research is yet perfect, there are many improvements that can be done in future research to support and improve this research. The suggestions that can be given for further research are:

1. Review the standardized and modules design through mechanical testing and calculation to further examine the feasibility of design.

2. Consider the production schedule for other products in the company as consideration for standardized part and module production.
3. Consider modularity development among 4, 6, and 10-wheels product.
4. Review inventory calculation for larger time horizon and more detail constraints
5. Calculate the cost for modularity implementation in larger scope, not only holding cost and labour cost
6. Consider stochastic demand for further calculation and analysis
7. Do detail layout analysis by considering work flow

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APPENDIX A: Similar Components for 4-Wheels Aluminium and Composite Full Box

No	Comp Code	Item Name	Unit	Material QTY
1	AV-14-POT	AV Pillar Cut	2	rod
2	AV-19-POT	AV Roof Circumference Cut	2	rod
3	AV-19-POT	AV Roof Circumference Cut	2	rod
4	AV-20-POT	AV Roof Lis Cut	2	rod
5	AV-20-POT	AV Roof Lis Cut	2	rod
6	AV-30-POT	AV Door Lis New Cut	1	rod
7	AV-18-POT	AV Frame Cut	4	rod
8	AV-18-POT	AV Frame Cut	4	rod
9	ST-BUNP.50	UNP 50x38x5x6	3.3	m
10	ST-BUNP.65	UNP 65x42x5x6	1	m
11	ST-ACB28.178	Alm Roof 4-wheels	3	Sht
12	ST-ACB09B.17	Iron Lateral 1735	5	rod
13	ST-PP.0030.1	Black Plate Cut 0030x0130x2	10	rod
14	ST-BS.50	Elbow 50x50x6	0.03	m
15	ST-PP.0030.2	Black Plate Cut 0030x1200x2	0.6	sht
16	ST-BPG.1.RC	Ring (Gas pipe 1"x1.5 cm)	4	pcs
17	ST-BPG.1.RC	Back door pipe P.1490 (S.10)	2	rod
18	ST-ACB22A	Fin 4-wheels	4	pcs
19	ST-ACB31A	Hollow shield 4-wheels	6	rod
20	ST-ACB06D	Elbow profile 20x30xP.1200	2	rod
21	ST-ACB19	4-wheels slebor	4	pcs
22	ST-ACB29	Wood lid	1	rod
23	ST-ACB06E	Elbow profile 30x30xP.1200	6	rod
24	ST-ACB06G.SE	Safety Light Set 4-wheels	2	Set
25	LL-M.01	White Melamine	2	Sht
26	LL-LK	Lamp Cable	14	m
27	LL-LS.04	Aluminum Lis H	4	m
28	LL-KR.05	Rubber Door YKK Type A	1.49	m
29	LL-R.02	Rivet 649	140	pcs
30	LL-KR.06	Rubber Door YKK Type B	7.84	m
31	LL-R.03	Rivet 675	24	pcs
32	LL-BPY.1	Bolt Thumbtack 5/16x20	46	pcs
33	LL-RP.01	Plate Ring 5/16 Yellow	20	pcs
34	LL-RV.01	Ring Ver 5/16	72	pcs
35	LL-RV.01	Ring Ver 5/16	38	pcs
36	LL-LS.04	Aluminum Lis H	8	m
37	LL-RP.01	Plate Ring 5/16 Yellow	14	pcs
38	LL-EL.02	Electrode 3.2	3	pcs
39	LL-BP.1	Bolt Nut 5/16 x 3/4 White	24	pcs
40	LL-R.03	Rivet 675	210	pcs
41	LL-LS.01	Lis Aluminum Hook	3.5	m
42	LL-R.03	Rivet 675	4	pcs
43	LL-RV.04	Ring Ver 1/4	4	pcs
44	LL-RV.01	Ring Ver 5/16	48	pcs
45	LL-P.16	Aluminum Short Pipe Clamp	4	pcs
46	LL-P.04	Long Pipe Clamp	2	pcs
47	LL-P.20	New Box Hinge	6	pcs
48	LL-P.10	Handle	2	Set
49	LL-P.07	Hook	4	pcs
50	LL-P.08	Top Hook House	1	pcs

No	Comp Code	Item Name	Unit	Material QTY
51	LL-P.09	Bottom Hook House	1	pcs
52	LL-BPY.1	Bolt Thumbtack 5/16x20 UCP	48	pcs
53	LL-RP.01	Plate Ring 5/16 Yellow	18	pcs
54	LL-LED.01	Red LED Lamp	2	pcs
55	LL-LED.02	Yellow LED Lamp	2	pcs
56	LL-WB.L.01	MS-168 Lamp	1	pcs
57	LL-LS	Lamp Switch	1	pcs
58	LL-LK	Lamp Cable	8	m
59	LL-R.02	Rivet 649	48	pcs
60	LL-SK	Aluminum Head Elbow	4	pcs
61	LL-ST	Tube Fuse	1	pcs
62	LL-RSK	Fuse House	1	pcs
63	LL-LSOC	Plus/minus socket	1	Set
64	LL-LFK	Spiral Cable	8	m
65	LL-BH.2	Bolt Nut 3/8x1 Black	8	pcs
66	LL-BH.3	Bolt Nut 3/8x4 Black	6	pcs
67	LL-RP.02	Plate Ring 3/8	16	pcs
68	LL-RV.02	Ring Ver 3/8	16	pcs
69	LL-RV.05	Ring Ver 5/8	16	pcs
70	LL-K.02	Kawel 35 (5/8x14x3 1/32)	4	pcs
71	LL-K.03	Kawel 40 (5/8x16x3 1/32)	4	pcs
72	LL-KK.01	Kawel 5/8 Clamp	8	pcs
73	LL-EL.02	Electrode 3.2	20	pcs
74	LL-A.2	Sandpaper 150	0.5	m
75	LL-C.03	Zincromate	0.25	Kg
76	LL-C.02	NC Silver	0.75	Kg
77	LL-CDB	Delta Sinthetic High Gloss Enamel D-Black	1	Tin
78	LL-TH.01	Super Thinner	2	Ltr
79	LL-RP.02	Plate Ring 3/8	4	pcs
80	LL-RV.01	Ring Ver 5/16	4	pcs
81	LL-KR.01	Body Plug Rubber	32	pcs
82	LL-R.01	Rivet 450	15	pcs
83	LL-R.03	Rivet 675	22	pcs
84	LL-EL.02	Electrode 3.2	2	pcs
85	LL-BS	Bracket Sills Full Box	4	pcs
86	LL-KR.12	Hinge Rubber	2	pcs
87	LL-KR4R	4-wheels rubber (28x34)	2	Sht
88	LL-BJ.3	Bolt Nut JP 5x20	4	pcs
89	LL-RP.04	Plate Ring 1/4 Yellow	4	pcs
90	LL-LAK	Small ACB Label ISO Logo	2	pcs
91	LL-LAB	Large ACB Label ISO Logo	1	pcs
92	LL-STCL	PT. X Logo Sticker	1	pcs
93	LL-STCB	New PT. X Sticker	1	pcs

APPENDIX B: Flow Process Chart of Current System

SUMMARY			DETAIL								
	No	Time (min)	Job : FLOOR SUB-ASSEMBLY (Rakit Lantai)								
Operation	51	89.95									
Transportation	2	0.70									
Delay	0	0.00	Type: ■ Material □ Worker □ Machine						Chart No : 1 of 11		
Inspection	1	0.47	Method: ■ Present □ Proposed						Date : January 2016		
Inventory	1	0.00	Chart Start :	Components					Created by : Viona Claresta		
Total	**55**	**91.12**	Chart End :	Floor Sub-Assembly					Checked by : PT Adicitra Bhirawa		

Activity	Operation	Transportation	Delay	Inspection	Inventory	Operation Duration (sec)	Moving Duration (sec)	Delay Duration (sec)	Material	Equipment
Preparation	●					228.09				
Measurement	●					236.29				
Cutting: mounting support	●					233.28			Siku 40x40x6	
Welding: 4 points	●					120.61				Welding rod
Welding: 12 points right	●					185.79				Welding rod
Welding: 12 points left	●					184.55				Welding rod
Welding: 24 points right	●					486.36				Welding rod
Welding: 24 points left	●					426.87				Welding rod
Installing: *rusukkanan*	●					186.66			UNP 50x38x5x6	
Installing: *rusuk fondasi bawah*	●					285.68			UNP 65x42x5x6	
Attaching: lower framework (2 points)	●					201.28				
Painting (covering welding points)	●					187.28				
Transportation		●					26.9			Hoist
Centering	●					40.87				
Painting preparation	●					161.23				
Painting	●					216.42				
Transportation		●					14.95			
Painting	●					270.57				
Arranging aluminum panel	●					61.34				
Attaching panel 1	●					15.81			AV Lantai Pot (1)	
Drilling	●					83.05				Hand Drilling Machine
Attaching bolts and nuts	●					31.70			Ring Ver 1/4, Baut Mur 6x16 hitam, Ring plat 1/4 kuning	
Attaching panel 2	●					10.18			AV Lantai Pot (1)	
Drilling	●					86.20				Hand Drilling Machine
Attaching bolts and nuts	●					31.02			Ring Ver 1/4, Baut Mur 6x16 hitam, Ring plat 1/4 kuning	
Attaching panel 3	●					17.8			AV Lantai Pot (1)	
Drilling	●					87.65				Hand Drilling Machine
Attaching bolts and nuts	●					36.65			Ring Ver 1/4, Baut Mur 6x16 hitam, Ring plat 1/4 kuning	
Attaching panel 4	●					15.4			AV Lantai Pot (1)	
Drilling	●					78.95				Hand Drilling Machine

SUMMARY			DETAIL		
	No	Time (min)	Job : FLOOR SUB-ASSEMBLY (Rakit Lantai)		
Operation	23	19.83			
Transportation	0	0.00			
Delay	0	0.00	Type: ■ Material □ Worker □ Machine		Chart No : 1 of 11 (con't)
Inspection	1	0.00	Method: ■ Present □ Proposed		Date : January 2016
Inventory	1	0.00	Chart Start :	Components	Created by : Viona Claresta
Total	25	19.83	Chart End :	Floor Sub-Assembly	Checked by : PT Adicitra Bhirawa

Activity	Operation	Transportation	Delay	Inspection	Inventory	Operation Duration (sec)	Moving Duration (sec)	Delay Duration (sec)	Material	Equipment
Attaching bolts and nuts	○	⇨	D	□	▽	33.11			Ring Ver 1/4, Baut Mur 6x16 hitam, Ring plat 1/4 kuning	
Attaching panel 5	○	⇨	D	□	▽	17.19			AV Lantai Pot (1)	
Drilling	○	⇨	D	□	▽	77.66				Hand Drilling Machine
Attaching bolts and nuts	○	⇨	D	□	▽	35.25			Ring Ver 1/4, Baut Mur 6x16 hitam, Ring plat 1/4 kuning	
Attaching panel 6	○	⇨	D	□	▽	19.47			AV Lantai Pot (1)	
Drilling	○	⇨	D	□	▽	84.15				Hand Drilling Machine
Attaching bolts and nuts	○	⇨	D	□	▽	31.95			Ring Ver 1/4, Baut Mur 6x16 hitam, Ring plat 1/4 kuning	
Attaching panel 7	○	⇨	D	□	▽	18.57			AV Lantai Pot (1)	
Drilling	○	⇨	D	□	▽	68.64				Hand Drilling Machine
Attaching bolts and nuts	○	⇨	D	□	▽	31.20			Ring Ver 1/4, Baut Mur 6x16 hitam, Ring plat 1/4 kuning	
Attaching panel 8	○	⇨	D	□	▽	16.26			AV Lantai Pot (1)	
Drilling	○	⇨	D	□	▽	61.61				Hand Drilling Machine
Attaching bolts and nuts	○	⇨	D	□	▽	34.65			Ring Ver 1/4, Baut Mur 6x16 hitam, Ring plat 1/4 kuning	
Attaching panel 9	○	⇨	D	□	▽	14.26			AV Lantai Pot (1)	
Drilling	○	⇨	D	□	▽	72.24				Hand Drilling Machine
Attaching bolts and nuts	○	⇨	D	□	▽	32.67			Ring Ver 1/4, Baut Mur 6x16 hitam, Ring plat 1/4 kuning	
Attaching panel 10	○	⇨	D	□	▽	16.15			AV Lantai Pot (1)	
Drilling	○	⇨	D	□	▽	79.73				Hand Drilling Machine
Attaching bolts and nuts	○	⇨	D	□	▽	32.93			Ring Ver 1/4, Baut Mur 6x16 hitam, Ring plat 1/4 kuning	
Attaching panel 11	○	⇨	D	□	▽	15.18			AV Lantai Pot (1)	
Drilling	○	⇨	D	□	▽	86.63				Hand Drilling Machine
Attaching bolts and nuts	○	⇨	D	□	▽	31.63			Ring Ver 1/4, Baut Mur 6x16 hitam, Ring plat 1/4 kuning	
Cutting	○	⇨	D	□	▽	250.85				Hand grinding machine
Inspection	○	⇨	D	□	▽	28.00				
Inventory	○	⇨	D	□	▽					

SUMMARY			DETAIL		
	No	Time (min)	Job :		
Operation	8	33.22	**FRAME SUB-ASSEMBLY** (Rakit Kusen)		
Transportation	0	0.00			
Delay	0	0.00	**Type:** ■ Material □ Worker □ Machine		**Chart No :** 2 of 11
Inspection	2	4.58	**Method:** ■ Present □ Proposed		**Date :** January 2016
Inventory	1	0.00	**Chart Start :**	Components	**Created by :** Viona Claresta
Total	**11**	**37.79**	**Chart End :**	Frame Sub-Assembly	**Checked by :** PT Adicitra Bhirawa

Activity	Operation	Transportation	Delay	Inspection	Inventory	Operation Duration (sec)	Moving Duration (sec)	Delay Duration (sec)	Material	Equipment
Preparation						343.27				
Arranging aluminium plate						247.51			AV Kusen Samping Pot (2), AV Kusen Atas Pot (1), AV Kusen Bawah Pot (1)	
Measurement						96.67				Waterpass, measurement meter
Drilling						105.84				Hand drilling machine
Attaching bolts and nuts						77.04				
Inspection						262.52				Waterpass, measurement meter
Drilling (small holes), 4 sides @5 holes						185.75				Hand drilling machine
Drilling (big holes), 4 sides @5 holes						134.35				Hand drilling machine
Attaching bolts and nuts						532.4				
Inspection						12.14				Waterpass, measurement meter
Inventory										

SUMMARY			DETAIL		
	No	Time (min)	Job : FRONT WALL SUB-ASSEMBLY (Rakit Dinding Depan)		
Operation	14.00	35.52			
Transportation	1	2.53			
Delay	0	0.00	Type: ■ Material □ Worker □ Machine		Chart No : 3 of 11
Inspection	1	0.42	Method: ■ Present □ Proposed		Date : January 2016
Inventory	1	0.00	Chart Start :	Components	Created by : Viona Claresta
Total	17	38.48	Chart End :	Frame Sub-Assembly	Checked by : PT Adicitra Bhirawa

Activity	Operation	Transportation	Delay	Inspection	Inventory	Operation Duration (sec)	Moving Duration (sec)	Delay Duration (sec)	Material	Equipment
Preparation	○	⇨	D	□	▽	18.94			AV Tiang Pot (2), AV Alas Pot (1), AV Siku Atap Pot (1)	
Transportation	○	⇨	D	□	▽		152.08		AV Dinding Strip Pot (9), AV Angin-angin pot (1)	
Cutting: frame	○	⇨	D	□	▽	186.54				Hand grinding machine
Arranging aluminum panel	○	⇨	D	□	▽	188.90				
Aranging on pedestal	○	⇨	D	□	▽	33.71				
Measurement	○	⇨	D	□	▽	88.52				Measuring meter
Scrapping: edges	○	⇨	D	□	▽	229.79				Hand grinding machine
Installing: frame	○	⇨	D	□	▽	225.87				
Drilling and rivetting	○	⇨	D	□	▽	174.90			Rivet 649	Hand drilling machine, rivet gun
Install: machine cover	○	⇨	D	□	▽	152.26			Karet Spon	
Drilling and rivetting	○	⇨	D	□	▽	73.36			Rivet 649	Hand drilling machine, rivet gun
Attaching bolt	○	⇨	D	□	▽	529.03			Baut Mur Payung 5/16 (18), Ring Plat 3/8 (18), Ring Ver 5/16 (18)	
Measurement	○	⇨	D	□	▽	34.95				Measuring meter
Drilling ventilation holes	○	⇨	D	□	▽	117.37				Hand drilling machine
Silicon	○	⇨	D	□	▽	52.37			Silicon glue	Silicon glue gun
Inspection	○	⇨	D	■	▽	25.29				
Inventory	○	⇨	D	□	▽					

SUMMARY			DETAIL		
	No	Time (min)	Job : ROOF SUB-ASSEMBLY (Rakit Atap)		
Operation	23	76.45			
Transportation	0	0.00			
Delay	0	0.00	Type: ■ Material □ Worker □ Machine		Chart No : 4 of 11
Inspection	1	0.72	Method: ■ Present □ Proposed		Date : January 2016
Inventory	0	0.00	Chart Start :	Components	Created by : Viona Claresta
Total	24	77.17	Chart End :	Floor Sub-Assembly	Checked by : PT Adicitra Bhirawa

Activity	Operation	Transportation	Delay	Inspection	Inventory	Operation Duration (sec)	Moving Duration (sec)	Delay Duration (sec)	Material	Equipment
Preparation	●					287.45				
Frame arranging	●					126.76			AV Lis Atap Pot 1750 (2), AV Lis Atap Pot 3000 (2)	
Attaching rivet	●					249.32			Rivet 649	Rivet gun
Drilling	●					112.79				Hand drilling machine
Marking	●					108.43				Marker
Attach *rusuk besi*	●					32.35			Rusuk besi 1735	
Glue *rusuk besi*	●					186.55			Silicon glue	Silicon glue gun
Drilling	●					287.53				Hand drilling machine
Attaching rivet	●					328.5			Rivet 649	Rivet gun
Inspection				●		23.38				Waterpass, measurement meter
Transportation (take melamine board and plat)		●				132.55				
Attach *plat penguat atap*	●					145.59			Atap alm 4 roda (3)	
Glue *plat penguat atap*	●					95.65			Silicon glue	Silicon glue gun
Attach rivet	●					620.38			Rivet 649	Rivet gun
Marking	●					45.07				Marker
Attach melamine board	●					189.03			Melamine putih (2)	
Attach rivet to melamine board	●					278.6			Rivet 649	Rivet gun
Attach lamp cable	●					242.6			Kabel lampu, Electrode 3.2	
Attach *plat penguat atap*	●					72.49			Plat potong penguat atap 0100x0100 (4), plat hitam potong 0030x0130x2 (10), plat hitam potong 0300x1200x2	
Attach rivet to *plat penguat atap*	●					256.74			Rivet 649	Rivet gun
Cutting edge	●					199.54				Hand grinding machine
Attach *keliling atap*	●					210.02			AV keliling atap Pot 1805 (2), AV keliling atap pot 3048 (2)	
Fixation glue	●					312.98			Silicon glue	Silicon glue gun
Inspection				●		43.27				Waterpass, measurement meter
Inventory					●					

SUMMARY			DETAIL		
	No	Time (min)	Job : BOX WALL ASSEMBLY (Rakit Box)		
Operation	9	76.35			
Transportation	2	3.90			
Delay	0	0.00	Type: ■ Material □ Worker □ Machine		Chart No : 6 of 11
Inspection	2	2.14	Method: ■ Present □ Proposed		Date : January 2016
Inventory	1	0.00	Chart Start : Components		Created by : Viona Claresta
Total	14	82.39	Chart End : Frame Sub-Assembly		Checked by : PT Adicitra Bhirawa

Activity	Operation	Transportation	Delay	Inspection	Inventory	Operation Duration (sec)	Moving Duration (sec)	Delay Duration (sec)	Material	Equipment
Preparation						600				
Arranging aluminum panel						303.41			AV Dinding Strip Pot (10)	
Preparation						110.46				
Arranging aluminum panel						300.89			AV Dinding Strip Pot (10)	
Scrapping						172.3				Hand grinding machine
Installing: frame						540			Frame Sub-Assembly (1), AV Alas Pot (2), AV Siku Atap Pot (2), Rivet 649, Baut Mur 5/16, Baut Mur Payung 5/16x20 UCP, Baut Mur Payung 5/16 x 1.5 Putih	
Transportation							23.6			
Installing: front part						117.78			Rivet 649, Baut Mur 5/16, Baut Mur Payung 5/16x20 UCP, Baut Mur Payung 5/16 x 1.5 Putih, Ring Plat 5/16 kuning, Ring Plat 3/8, Ring Ver 5/16	
Installing: right wall						980.65				
Installing: left wall						1029.3				
Inspection						128.25				

SUMMARY			DETAIL								
	No	Time (min)	Job : MELAMINE+ROOF ASSEMBLY (Pasang Melamine dan Atap)								
Operation	16	65.15									
Transportation	2	7.01									
Delay	0	0.00	Type: ■ Material □ Worker □ Machine						Chart No : 7 of 11		
Inspection	1	5.00	Method: ■ Present □ Proposed						Date : January 2016		
Inventory	0	0.00	Chart Start :	Box Assembly					Created by : Viona Claresta		
Total	19	77.16	Chart End :	Melamine+Roof Assembly					Checked by : PT Adicitra Bhirawa		

Activity	Operation	Transportation	Delay	Inspection	Inventory	Operation Duration (sec)	Moving Duration (sec)	Delay Duration (sec)	Material	Equipment
Preparation	●					300				
Transportation melamine components		●					210.4			
Installing: *lis aluminium*	●					263.2			Lis aluminium H, Lis Aluminium Pancing	
Drilling	●					152.8				Hand drilling machine
Attaching rivet	●					262.32			Rivet 675, Ring Ver 5/16, Baut Mur 5/16	Rivet gun
Installing: *plat*	●					288.55			Plat hitam potong 0300x1200x2, Omega1530	
Drilling	●					231.8				Hand drilling machine
Attaching rivet	●					128.4			Rivet 675, Ring Plat 5/16 kuning, Baut Mur 5/16	Rivet gun
Installing: *multiplek*	●					378.2			Multiplek, Electrode 3.2	
Drilling	●					143.2				Hand drilling machine
Attaching rivet	●					176.9			Rivet 675, Ring Plat 5/16 kuning, Baut Mur 5/16	Rivet gun
Transportation		●					210.3			
Assembly: *frame sub-assembly*	●					298.60			Frame sub-assembly	
Drilling	●					143.1				Hand drilling machine
Attaching rivet	●					128.6			Rivet 675	Rivet gun
Installing: *atap sub-assembly*	●					436.7			Roof sub-assembly	
Drilling	●					156.75				Hand drilling machine
Attaching rivet	●					124.98			Rivet 675	Rivet gun
Inspection				●		300				

SUMMARY			DETAIL							
	No	Time (min)	Job : BACK DOOR ASSEMBLY (Pasang Pintu Belakang)							
Operation	5	24.36								
Transportation	1	2.94								
Delay	0	0.00	Type: ■ Material □ Worker □ Machine						Chart No : 8 of 11	
Inspection	1	3.33	Method: ■ Present □ Proposed						Date : January 2016	
Inventory	0	0.00	Chart Start :	Melamine+Roof Assembly					Created by : Viona Claresta	
Total	7	30.64	Chart End :	Box+Back Door Assembly					Checked by : PT Adicitra Bhirawa	

Activity	Operation	Transportation	Delay	Inspection	Inventory	Operation Duration (sec)	Moving Duration (sec)	Delay Duration (sec)	Material	Equipment
Preparation	○	⇨	D	□	▽	300				
Transportation back door parts	○	⇨	D	□	▽		176.4			
Arrange back door to frame	○	⇨	D	□	▽	445.8			Back door sub-assembly	
Marking	○	⇨	D	□	▽	32.7				Marker
Welding handle to back door	○	⇨	D	□	▽	298.4			Klem pipa pendek, klem pipa panjang, handel, klathok, pengait, rumah pengait atas, rumah pengait bawah	Welding rod
Attach back door to frame	○	⇨	D	□	▽	188.30			Siku penguat kusen, Ring cincin, Pipa pintu belakang, Baut mur JF 6x20, Baut mur payung 5/16, Ring plat 5/16 kuning, Ring ver 1/4, Ring ver 5/16, Electrode 2.6	
Inspection	○	⇨	D	□	▽	200				Hand drilling machine

SUMMARY			DETAIL							
	No	Time (min)	Job : LAMP ASSEMBLY (Pasang Lampu)							
Operation	8	18.22								
Transportation	1	2.50								
Delay	0	0.00	Type: ■ Material □ Worker □ Machine						Chart No : 9 of 11	
Inspection	1	3.33	Method: ■ Present □ Proposed						Date : January 2016	
Inventory	0	0.00	Chart Start :	Melamine+Roof Assembly					Created by : Viona Claresta	
Total	10	24.06	Chart End :	Box+Back Door Assembly					Checked by : PT Adicitra Bhirawa	

Attaching: rivet	Operation	Transportation	Delay	Inspection	Inventory	Operation Duration (sec)	Moving Duration (sec)	Delay Duration (sec)	Material	Equipment
Preparation	●					300				
Transportation parts		⇨					150			
Installing: cable	●					114.3			Kabel lampu, flexible kabel (spiral)	
Installing: lamp	●					129.31			Lampu LED merah, Lampu LED Kuning, Lampu MS-168	
Installing: electrical components	●					134.3			Skakel lampu, Sekring, rumah tabung, socket plus/minus	
Soldering	●					18.40				Solder
Inspection	●					200				
Installing: *Siku kop aluminium*	●					96.4			Siku kop aluminium	
Drilling	●					67.65				Hand drilling machine
Attaching: rivet	●					36.4			Rivet 649	Rivet gun

SUMMARY			DETAIL		
	No	Time (min)	Job : *KAWEL* ASSEMBLY (Pasang Kawel)		
Operation	9	50.68			
Transportation	1	2.18			
Delay	0	0.00	Type: ■ Material □ Worker □ Machine		Chart No : 10 of 11
Inspection	1	5.00	Method: ■ Present □ Proposed		Date : January 2016
Inventory	0	0.00	Chart Start :	Melamine+Roof Assembly	Created by : Viona Claresta
Total	11	57.85	Chart End :	Box+Back Door Assembly	Checked by : PT Adicitra Bhirawa

Activity	Operation	Transportation	Delay	Inspection	Inventory	Operation Duration (sec)	Moving Duration (sec)	Delay Duration (sec)	Material	Equipment
Preparation	●	⇨	D	□	▽	300				
Transportation of parts	○	⇨	D	□	▽		130.5			
Installing: perisai	●	⇨	D	□	▽	552.4			Perisai kolong 4 roda	
Installing: penahan perisai	●	⇨	D	□	▽	482.9			Profil siku 20x30x1200, Profil siku 30x30x1200	Screwdriver
Installing: penahan lampu	●	⇨	D	□	▽	230.8			Set pengaman lampu 4 roda	
Installing: wood cover	●	⇨	D	□	▽	140.30			Kayu LVL Hardwood 6x10x400	
Installing: slebor besar	●	⇨	D	□	▽	165.7			Slebor 4 roda	
Installing: penahan slebor	●	⇨	D	□	▽	182.8			UNP 65x42x5x6	
Installing: slebor mini	●	⇨	D	□	▽	260.6			Sirip 4 roda	
Installing: bracket	●	⇨	D	□	▽	430.1			Kawel 35, Kawel 40, Tutup kayu, pipa gas, Klem kawel, Electrode 3.2	
Inspection	●	⇨	D	□	▽	300				

SUMMARY			DETAIL								
	No	Time (min)	Job : FINISHING (Finishing)								
Operation	5	17.60									
Transportation	0	0.00									
Delay	0	0.00	Type: ■ Material □ Worker □ Machine						Chart No : 11 of 11		
Inspection	1	3.04	Method: ■ Present □ Proposed						Date : January 2016		
Inventory	0	0.00	Chart Start : Melamine+Roof Assembly						Created by : Viona Claresta		
Total	6	20.63	Chart End : Box+Back Door Assembly						Checked by : PT Adicitra Bhirawa		

Activity	Operation	Transportation	Delay	Inspection	Inventory	Operation Duration (sec)	Moving Duration (sec)	Delay Duration (sec)	Material	Equipment
Preparation										
Painting: pipe						338.7			Zincromate, NC Silver, Thinner Supper, Delta Sintetic High Gloss Enamel	Brush, Amplas 150
Painting: hinge (engsel pintu)						83.36				
Painting: slebor kiri bawah						125.92				
Painting: slebor kanan bawah						114.78				
Attaching: Adicitra label and sticker						213.84			Sticker logo adicitra, sticker adicitra baru, label ABC kecil, label ABC besar	
Final Inspection						182.19				

APPENDIX C: Flow Process Chart of Proposed System

SUMMARY			DETAIL			
	No	Time (min)	Job : S1 (Rakit Chasis Standard)			
Operation	13	50.59				
Transportation	1	0.45				
Delay	0	0.00	Type: ■ Material □ Worker □ Machine			Chart No : 1 of 4
Inspection	1	0.54	Method: □ Present ■ Proposed			Date : January 2016
Inventory	1	0.00	Chart Start :	Components		Created by : Viona Claresta
Total	**16**	**51.58**	Chart End :	Floor Sub-Assembly		Checked by : PT Adicitra Bhirawa

Activity	Operation	Transportation	Delay	Inspection	Inventory	Operation Duration (sec)	Moving Duration (sec)	Delay Duration (sec)	Material	Equipment
Preparation	●					228.09				
Measurement	●					236.29				
Cutting: mounting support	●					233.28			Siku 40x40x6	
Welding: 4 points	●					120.61				Welding rod
Welding: 12 points right	●					185.79				Welding rod
Welding: 12 points left	●					184.55				Welding rod
Welding: 24 points right	●					486.36				Welding rod
Welding: 24 points left	●					426.87				Welding rod
Installing: *rusukkanan*	●					186.66			UNP 50x38x5x6	
Installing: *rusuk fondasi bawah*	●					285.68			UNP 65x42x5x6	
Attaching: lower framework (2 points)	●					201.28				
Painting (covering welding points)	●					187.28				
Transportation		●					26.9			Hoist
Centering	●					40.87				
Inspection				●		32.51				
Inventory					●					

SUMMARY			DETAIL							
	No	Time (min)	Job : S2 (Rakit Atap Standard)							
Operation	13	46.32								
Transportation	0	0.00								
Delay	0	0.00	Type: ■ Material □ Worker □ Machine						Chart No : 2 of 4	
Inspection	2	1.11	Method: □ Present ■ Proposed						Date : January 2016	
Inventory	1	0.00	Chart Start : Components						Created by : Viona Claresta	
Total	**16**	**47.43**	Chart End : Floor Sub-Assembly						Checked by : PT Adicitra Bhirawa	

Activity	Operation	Transportation	Delay	Inspection	Inventory	Operation Duration (sec)	Moving Duration (sec)	Delay Duration (sec)	Material	Equipment
Preparation						287.45				
Frame arranging						126.76			AV Lis Atap Pot 1750 (2), AV Lis Atap Pot 3000 (2)	
Attaching rivet						249.32			Rivet 649	Rivet gun
Drilling						112.79				Hand drilling machine
Marking						108.43				Marker
Attach *rusuk besi*						32.35			Rusuk besi 1735	
Glue *rusuk besi*						186.55			Silicon glue	Silicon glue gun
Drilling						287.53				Hand drilling machine
Attaching rivet						328.5			Rivet 649	Rivet gun
Inspection						23.38				Waterpass, measurement meter
Transportation (take atap alm 4 roda)						132.55				
Attach *plat atap*						145.59			Atap alm 4 roda (3)	
Glue *plat atap*						95.65			Silicon glue	Silicon glue gun
Attach rivet						620.38			Rivet 649	Rivet gun
Inspection						43.27				Waterpass,
Inventory										

SUMMARY		
	No	**Time (min)**
Operation	16	38.80
Transportation	3	2.03
Delay	0	0.00
Inspection	1	8.36
Inventory	1	0.00
Total	**21**	**49.19**

DETAIL

Job : **M4A**
(Rakit Modul Pintu Aluminium)

Type: ■ Material □ Worker □ Machine — **Chart No :** 3 of 4

Method: □ Present ■ Proposed — **Date :** January 2016

Chart Start : Components — **Created by :** Viona Claresta

Chart End : Frame Sub-Assembly — **Checked by :** PT Adicitra Bhirawa

Activity	Operation	Transportation	Delay	Inspection	Inventory	Operation Duration (sec)	Moving Duration (sec)	Delay Duration (sec)	Material	Equipment
Preparation	●					600				
Arranging aluminum panel	●					227.68			AV Hollo Pot (8), AV angin-angin pot (1)	
Measurement	●					227.25				Ruler
Scrapping: edges	●					217.75				Hand held grinding tool
Scraping: upper	●					53.50				Hand held grinding tool
Transportation and cleaning		●					18.64			
Scrapping: lower	●					51.71				Hand held grinding tool
Transportation		●					19.64			
Installing ventilation holes	●					16.22				Hand held drilling tool
Cutting: siku 1	●					32.49			Siku Penguat Kusen	Hand held grinding tool
Cutting: siku 2	●					38.53			Siku Penguat Kusen	Hand held grinding tool
Transportation and cleaning		●					83.44			
Inserting *sok* to the back door	●					23.21			Sok pintu besar potong P.0020 (12)	
Hammering	●					12.32				Hammer
Installing upper frame	●					32.88			AV Frame Pot 1435 (1)	
Inserting *sok*	●					29.97			Sok pintu besar potong P.0030 (1)	
Installing lower frame	●					30.91			AV Frame Pot 1435 (1)	
Installing *sok*	●					19.81			Sok pintu besar potong P.0030 (1)	
Inspection				●		501.74				
Finishing	●					220.30				
Inventory					●					

SUMMARY			DETAIL			
	No	Time (min)	Job : M5A (Rakit Modul Lantai Aluminium)			
Operation	36	32.70				
Transportation	1	0.25				
Delay	0	0.00	Type: ■ Material □ Worker □ Machine			Chart No : 4 of 4
Inspection	1	0.00	Method: □ Present ■ Proposed			Date : January 2016
Inventory	1	0.00	Chart Start : Components			Created by : Viona Claresta
Total	39	32.95	Chart End : Floor Sub-Assembly			Checked by : PT Adicitra Bhirawa

Activity	Operation	Transportation	Delay	Inspection	Inventory	Operation Duration (sec)	Moving Duration (sec)	Delay Duration (sec)	Material	Equipment
Preparation	○	⇨	D	□	▽	216.42				
Transportation	○	⇨	D	□	▽		14.95			
Arranging aluminum panel	○	⇨	D	□	▽	61.34				
Attaching panel 1	○	⇨	D	□	▽	15.81			AV Lantai Pot (1)	
Drilling	○	⇨	D	□	▽	83.05				Hand Drilling
Attaching bolts and nuts	○	⇨	D	□	▽	31.70			Ring Ver 1/4, Baut Mur 6x16 hitam, Ring plat 1/4 kuning	
Attaching panel 2	○	⇨	D	□	▽	10.18			AV Lantai Pot (1)	
Drilling	○	⇨	D	□	▽	86.20				Hand Drilling Machine
Attaching bolts and nuts	○	⇨	D	□	▽	31.02			Ring Ver 1/4, Baut Mur 6x16 hitam, Ring plat 1/4 kuning	
Attaching panel 3	○	⇨	D	□	▽	17.8			AV Lantai Pot (1)	
Drilling	○	⇨	D	□	▽	87.65				Hand Drilling Machine
Attaching bolts and nuts	○	⇨	D	□	▽	36.65			Ring Ver 1/4, Baut Mur 6x16 hitam, Ring plat 1/4 kuning	
Attaching panel 4	○	⇨	D	□	▽	15.4			AV Lantai Pot (1)	
Drilling	○	⇨	D	□	▽	78.95				Hand Drilling Machine
Attaching bolts and nuts	○	⇨	D	□	▽	33.11			Ring Ver 1/4, Baut Mur 6x16 hitam, Ring plat 1/4 kuning	
Attaching panel 5	○	⇨	D	□	▽	17.19			AV Lantai Pot (1)	
Drilling	○	⇨	D	□	▽	77.66				Hand Drilling Machine
Attaching bolts and nuts	○	⇨	D	□	▽	35.25			Ring Ver 1/4, Baut Mur 6x16 hitam, Ring plat 1/4 kuning	
Attaching panel 6	○	⇨	D	□	▽	19.47			AV Lantai Pot (1)	
Drilling	○	⇨	D	□	▽	84.15				Hand Drilling Machine
Attaching bolts and nuts	○	⇨	D	□	▽	31.95			Ring Ver 1/4, Baut Mur 6x16 hitam, Ring plat 1/4 kuning	
Attaching panel 7	○	⇨	D	□	▽	18.57			AV Lantai Pot (1)	
Drilling	○	⇨	D	□	▽	68.64				Hand Drilling Machine

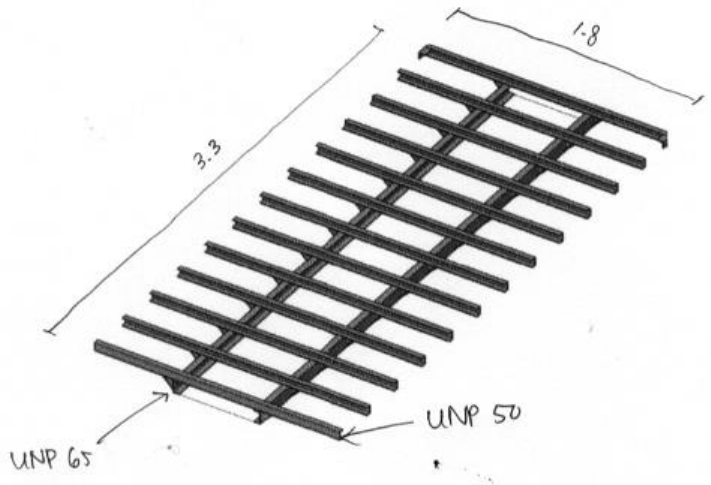
SUMMARY			DETAIL									
	No	Time (min)	Job : M5A (Rakit Modul Lantai Aluminium)									
Operation	15	14.54										
Transportation	0	0.00										
Delay	0	0.00	Type: ■ Material □ Worker □ Machine							Chart No : 4 of 4 (con't)		
Inspection	1	0.00	Method: □ Present ■ Proposed							Date : January 2016		
Inventory	1	0.00	Chart Start :	Components						Created by : Viona Claresta		
Total	17	14.54	Chart End :	Floor Sub-Assembly						Checked by : PT Adicitra Bhirawa		

Activity	Operation	Transportation	Delay	Inspection	Inventory	Operation Duration (sec)	Moving Duration (sec)	Delay Duration (sec)	Material	Equipment
Drilling	○	⇨	D	□	▽	68.64				Hand Drilling Machine
Attaching bolts and nuts	○	⇨	D	□	▽	31.20			Ring Ver 1/4, Baut Mur 6x16 hitam, Ring plat 1/4 kuning	
Attaching panel 8	○	⇨	D	□	▽	16.26			AV Lantai Pot (1)	
Drilling	○	⇨	D	□	▽	61.61				Hand Drilling Machine
Attaching bolts and nuts	○	⇨	D	□	▽	34.65			Ring Ver 1/4, Baut Mur 6x16 hitam, Ring plat 1/4 kuning	
Attaching panel 9	○	⇨	D	□	▽	14.26			AV Lantai Pot (1)	
Drilling	○	⇨	D	□	▽	72.24				Hand Drilling Machine
Attaching bolts and nuts	○	⇨	D	□	▽	32.67			Ring Ver 1/4, Baut Mur 6x16 hitam, Ring plat 1/4 kuning	
Attaching panel 10	○	⇨	D	□	▽	16.15			AV Lantai Pot (1)	
Drilling	○	⇨	D	□	▽	79.73				Hand Drilling Machine
Attaching bolts and nuts	○	⇨	D	□	▽	32.93			Ring Ver 1/4, Baut Mur 6x16 hitam, Ring plat 1/4 kuning	
Attaching panel 11	○	⇨	D	□	▽	15.18			AV Lantai Pot (1)	
Drilling	○	⇨	D	□	▽	86.63				Hand Drilling Machine
Attaching bolts and nuts	○	⇨	D	□	▽	31.63			Ring Ver 1/4, Baut Mur 6x16 hitam, Ring plat 1/4 kuning	
Cutting	○	⇨	D	□	▽	250.85				Hand grinding machine
Inspection	○	⇨	D	□	▽	28.00				
Inventory	○	⇨	D	□	▽					

APPENDIX D: Practical Analysis Result (FGD) of Modules

LEMBAR ANALISA MODUL

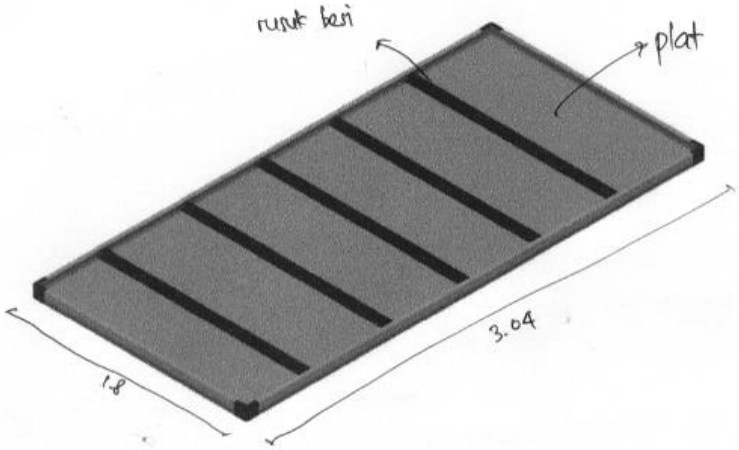
Modul : S1 (Chassis)
Diajukan Oleh : Viona Claresta
Ditinjau Oleh : Pak Suroto
Tanggal : 5 Januari 2016
Gambar :



Catatan : Diterima

LEMBAR ANALISA MODUL

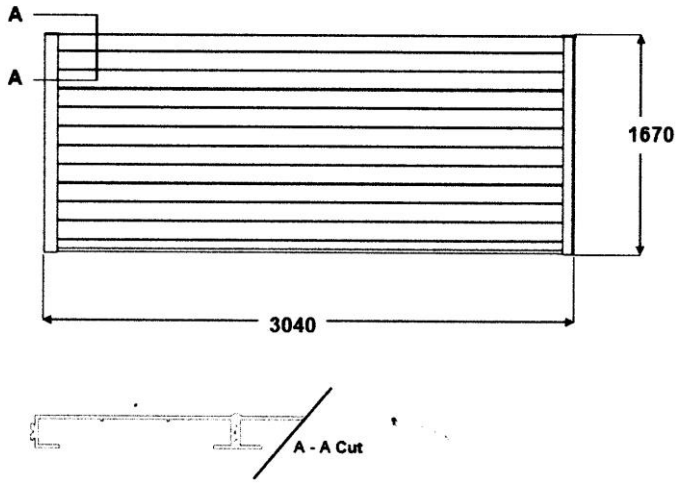
Modul : S2 (Atap)
Diajukan Oleh : Viona Claresta
Ditinjau Oleh : Pak Sucito, Pak Tino
Tanggal : 5 Januari 2016
Gambar :



Catatan : Diterima

LEMBAR ANALISA MODUL

Modul : **M1A (Dinding Aluminium)**
Diajukan Oleh : **Viona Claresta**
Ditinjau Oleh : Pak Sutoto
Tanggal : 5 Januari 2016
Gambar :

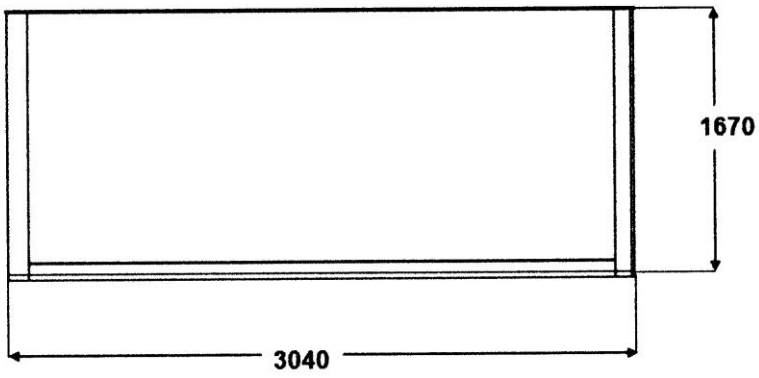


Catatan : Ditolak

- Terlalu besar, memakan banyak tempat → mahal biaya
- Komponen (AV) dibutuhkan di produk lain, rugi jika hanya disimpan sebagai modul.

LEMBAR ANALISA MODUL

Modul : **M1B (Dinding Composite)**
Diajukan Oleh : **Viona Claresta**
Ditinjau Oleh : Pak Sucoto
Tanggal : 5 Januari 2016
Gambar :

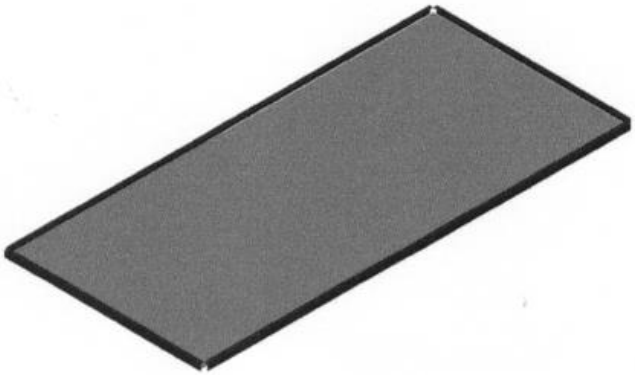


Catatan : Ditolak

- Komponen composite memiliki pelapis (sticker) saat belum diproses, jika dijadikan modul dinding, sticker harus dilepas → jika hanya disimpan saja maka composite jadi cepat rusak.

LEMBAR ANALISA MODUL

Modul : **M2A (Atap Aluminium)**
Diajukan Oleh : **Viona Claresta**
Ditinjau Oleh : Pak Sucoro, Pak Tino
Tanggal : 5 Januari 2016
Gambar :

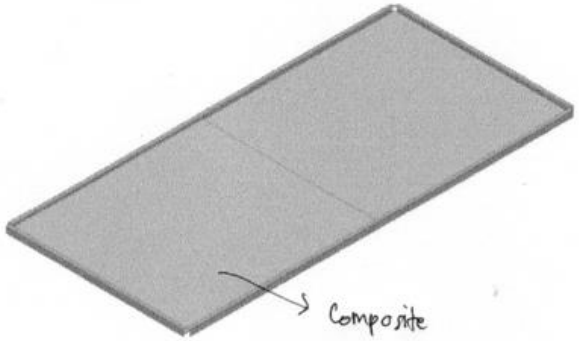


Catatan : Ditolak

- Komponen hanya berupa papan, akan menghabiskan tempat
- Aluminium (AV) yang digunakan harganya mahal dan juga dibutuhkan u/ produk lain selain roda - 4 → pembuatan modul hanya akan menyita banyak resources.

LEMBAR ANALISA MODUL

Modul : **M2B (Atap Composite)**
Diajukan Oleh : **Viona Claresta**
Ditinjau Oleh : Pak Sucoro, Pak Tino
Tanggal : 5 Januari 2016
Gambar :

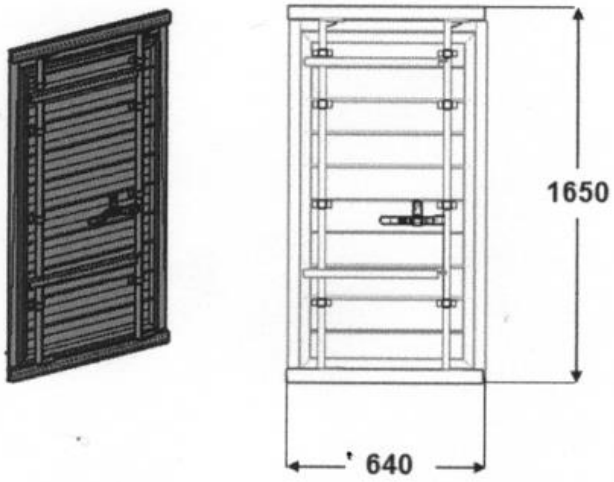


Catatan : Ditolak

- Komponen hanya berupa papan, akan memakan tempat terlalu banyak
- Composite saat penyimpanan dilapisi sticker, jika dirakit maka sticker dilepas → jika tdk dipasang ke mobil / jika disimpan lagi composite mudah rusak.

LEMBAR ANALISA MODUL

Modul : **M3A (Pintu Samping Aluminium)**
Diajukan Oleh : **Viona Claresta**
Ditinjau Oleh : Pak Suroto , Pak Tino
Tanggal : 5 Januari 2016
Gambar :

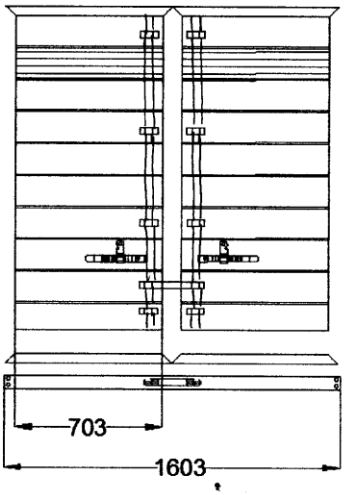


Catatan :

-Desain sesuai, tetapi trend permintaan pelanggan semakin jarang ↓ pintu samping dicoda 4. Sepertinya akan sia-sia jika dimodulkan.
- Pesanan pintu samping → custom. ~~tinggi~~ tinggi variasi

LEMBAR ANALISA MODUL

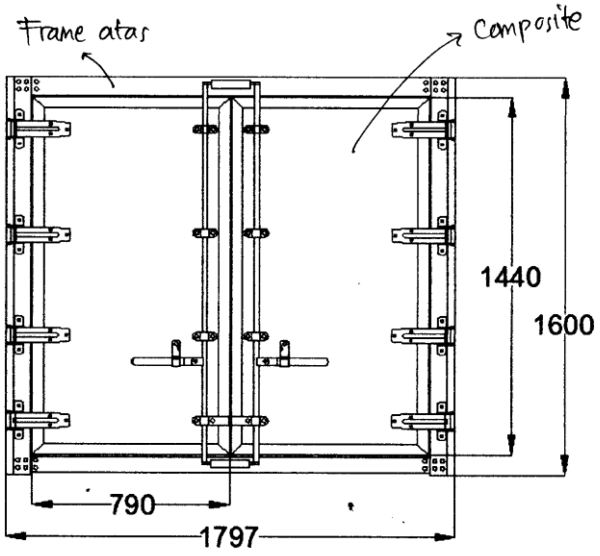
Modul : **M4A (Pintu Aluminium)**
Diajukan Oleh : **Viona Claresta**
Ditinjau Oleh : Pak Suroto
Tanggal : 5 Januari 2016
Gambar :



Catatan : Diterima.
Handle dan klatfhot jangan dipasang dulu → belakangan saja.
Frame samping menyesuaikan panjang pintu (tidak masuk modul)

LEMBAR ANALISA MODUL

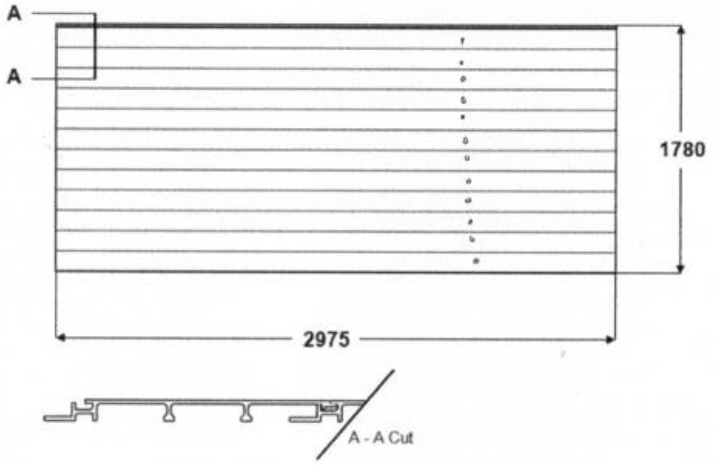
Modul : **M4B (Pintu Composite)**
Diajukan Oleh : **Viona Claresta**
Ditinjau Oleh : Pak Suroto
Tanggal : 5 Januari 2016
Gambar :



Catatan : Diterima
Frame atas seharusnya digabung atap (masuk bagian atap) → nanti ditinjau ulang

LEMBAR ANALISA MODUL

Modul : **M5A (Lantai Aluminium)**
Diajukan Oleh : **Viona Claresta**
Ditinjau Oleh : Pak Suroto, Pak Tino
Tanggal : 5 Januari 2016
Gambar :

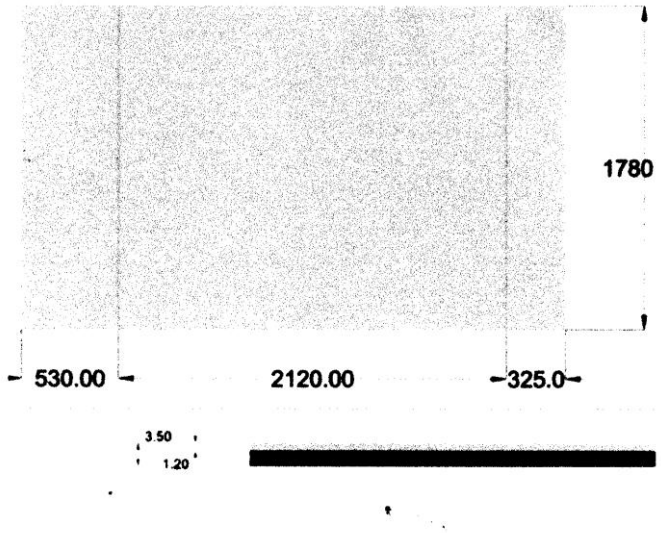


Catatan : Diterima

Dipasang dgn rivet.

LEMBAR ANALISA MODUL

Modul : **M5B (Lantai Composite)**
Diajukan Oleh : **Viona Claresta**
Ditinjau Oleh : Pak Suroto, Pak Tino
Tanggal : 5 Januari 2016
Gambar :



Catatan : Diterima

APPENDIX E: Production and Cost Analysis

No. Of Combinations	Standardized		Modules	Lead Time (min)	Prod. Capacity	Labour Cost/unit	Holding Cost
	Current System			377.4	1.27	Rp 3,459,500.00	Rp -
1	S1	S2	M4A + M5A	196.25	2.45	Rp 1,798,958.33	Rp 5,949,439.26
2	S1	S2	M4B + M5B	198.46	2.42	Rp 1,819,216.67	Rp 2,929,382.42
3	S1	S2	M4A	229.2	2.09	Rp 2,101,000.00	Rp 3,639,766.45
4	S1	S2	M4B	235.75	2.04	Rp 2,161,041.67	Rp 2,773,719.65
5	S1	S2	M5B	241.1	1.99	Rp 2,210,083.33	Rp 2,670,586.91
6	S1		M4A + M5A	243.68	1.97	Rp 2,233,733.33	Rp 4,125,395.39
7	S1	S2	M5A	245.44	1.96	Rp 2,249,866.67	Rp 4,824,596.95
8	S1		M4B + M5B	245.89	1.95	Rp 2,253,991.67	Rp 1,105,338.55
9		S2	M4A + M5A	247.83	1.94	Rp 2,271,775.00	Rp 5,258,559.00
10		S2	M4B + M5B	250.04	1.92	Rp 2,292,033.33	Rp 2,238,502.16
11	S1		M4A	276.63	1.74	Rp 2,535,775.00	Rp 1,815,722.57
12	S1	S2		278.39	1.72	Rp 2,551,908.33	Rp 2,514,924.14
13		S2	M4A	280.78	1.71	Rp 2,573,816.67	Rp 2,948,886.18
14	S1		M4B	283.18	1.70	Rp 2,595,816.67	Rp 949,675.78
15		S2	M4B	287.33	1.67	Rp 2,633,858.33	Rp 2,082,839.39
16	S1		M5B	288.53	1.66	Rp 2,644,858.33	Rp 846,543.03
17		S2	M5B	292.68	1.64	Rp 2,682,900.00	Rp 1,979,706.64
18	S1		M5A	292.87	1.64	Rp 2,684,641.67	Rp 3,000,553.08
19			M4B + M5B	295.26	1.63	Rp 2,706,550.00	Rp 414,458.28
20		S2	M5A	297.02	1.62	Rp 2,722,683.33	Rp 4,133,716.69
21			M4A + M5A	297.47	1.61	Rp 2,726,808.33	Rp 3,434,515.13

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BIOGRAPHY

Viona Claresta is the last daughter of Tarya, S.E., and Ketut Ginarti, who was born in Denpasar, on October 4TH, 1994. Author started her education at SD Cipta Dharma, and continued to SMP Negeri 1 Denpasar. Her high school years passed in SMA Negeri 3 Denpasar, before finally pursued her study at Industrial Engineering Department of ITS in 2012.

During her college life, the author is member of International Class which use English as working language. She also actively joined students organization such as Himpunan Mahasiswa Teknik Industri and also Badan Eksekutif Mahasiswa – FTI. She was staff of Internal Affair Department BEM FTI ITS 2013/2014, and also staff of External Affair Department HMTI ITS 2013/2014. Then the author continued as the First Secretary of HMTI ITS 2014/2015.

In the other side, author also enhanced her academic knowledge by becoming one of assisstants in Manufacturing System Laboratory. During her college life, author ever receive scholarship from Djarum Foundation, Pembangunan Jaya, and Toyota – Astra.